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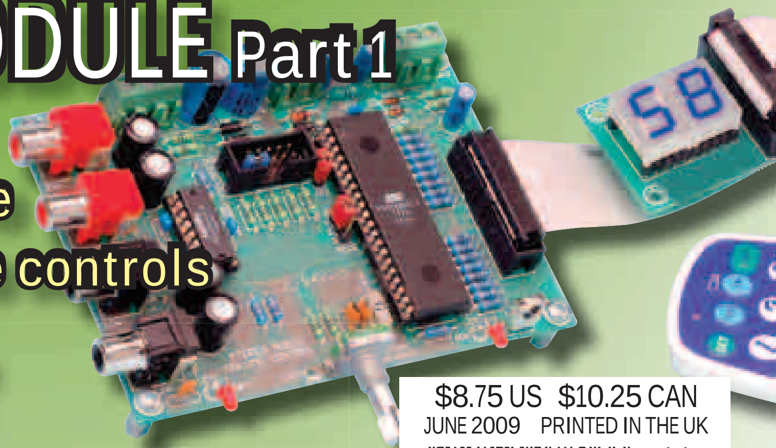

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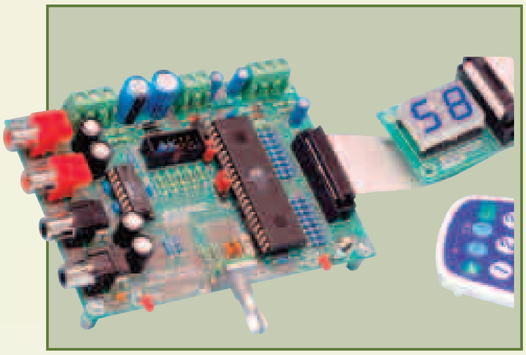

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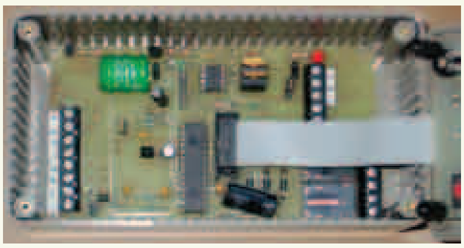

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Our July 2009 issue will be published on Thursday 11 June 2009, see page 72 for details.

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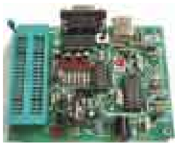

USB/Serial connection. Header cable for ICSP. Free Windows XP software. See website for PICs supported. ZIF Socket and USB lead extra. 18Vdc.
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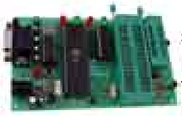

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. Supply: 16Vdc.
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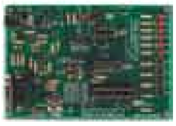
PIC Programmer & Experimenter Board



The PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments, such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times for experimenting at will. Software to compile and program your source code is included.
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Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

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Kit Order Code: 3153KT - **£24.95**
Assembled Order Code: AS3153 - **£34.95**

Telephone Call Logger

Stores over 2,500 x 11 digit DTMF numbers with time and date. Records all buttons pressed during a call. No need for any connection to computer during operation but logged data can be downloaded into a PC via a serial port and saved to disk. Includes a plastic case 130x100x30mm. Supply: 9-12V DC (Order Code PSU445).
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Interfacing non-Windows computers

For all the (sometimes evangelical) popularity of Apple Mac computers and Linux-based machines, there is no doubt that Windows PCs are far and away the most numerous kind of personal computer. For that reason, EPE concentrates almost exclusively on the 'Wintel' architecture/OS model. We know it's a little unfair and frustrating for those of you who choose to use a different computer, but until this near monopoly is broken there is little else that we can sensibly do without producing projects that only a small minority of readers will have any interest in building. I say this with more than a little regret because I am a convinced Mac user and would therefore like to see just a little bit more attention given to this elegant family of computers.

I bring this up now because we have recently received a request for a Linux project and a Mac interface question (to be published in Readout next month). So, after all the useful Nixie tube information readers were kind enough to send into this month's Readout following my April Editorial, I am hoping to tap into your knowledge again. Are there any Mac interface enthusiast who would like to share their knowledge via Readout or perhaps Ingenuity Unlimited? Advice could range from experience in driving USB ports or selecting I/O cards to building actual circuits and low-level programming packages.

EPE is not about to lose its commitment to supporting the vast majority of readers who happily and successfully run PC-Windows projects, but it seems reasonable to acknowledge that there is intelligent life outside the world of Vista and XP!

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All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

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We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

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NEWS

A roundup of the latest Everyday News from the world of electronics

Ultra-wide screen TVs

Philips says that "cinema will come home" with "no more black bars" after the commercial launch of the world's first ultra-wide screen 21:9 TVs. Barry Fox reports.

At a recent demonstration of preview sets in London, Philips showed widescreen cinema movie material on a 42-inch 16:9 LCD TV, and on a 56-inch Cinema 21:9 LCD set. The two sets have the same height screen and the 21:9 set clearly showed the advantage of completely filling the screen without black letterbox bars at the top and bottom.

Although Philips promises that conventional 16:9 broadcast programming, and even old 4:3 material, will look equally good thanks to intelligent auto-formatting, there was no demonstration of this crucial consideration.

"This is a pre-production sample without the necessary picture processing circuitry", said Consumer Marketing Director, Paul Hobden.

When some 16:9 material was accidentally fed to the 21:9 set during the demonstration, it displayed the on-screen message 'Video format not supported'.

Hobden explained that in the final set, 16:9 source material will be auto-expanded to fit the 21:9 screen by slightly stretching the outer edges, much as done when current 16:9 sets display 4:3 material. When 4:3 material is played through the new 21:9 sets, there will be some stretching, with black borders at the sides of the screen to complete the picture.

Some confusion arose during the London briefing over the slight mathematical difference between the exact cinema aspect ratio of 2.39:1 and the Cinema 21:9 (2.33:1) name used by Philips. Philips confirms that technically the set is "absolutely aligned with the cinema format" and the numerical ratio has been rounded to 21:9 "for marketing reasons".

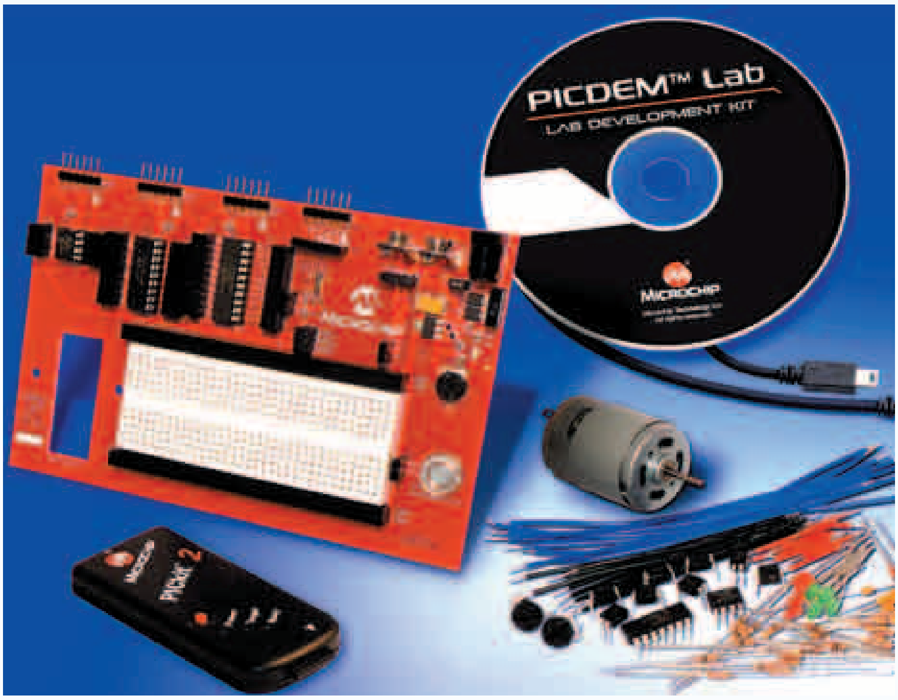
So no formatting and auto-expansion of the picture will be needed if the set is fed with true cinema format material. However, slight formatting and auto expansion may be needed with Blu-ray discs until the disc producers use the option in the BD standard to record true cinema format pictures.

PICDEM LAB DEVELOPMENT KIT UNVEILED

Microchip has announced the PICDEM Lab Development Kit, a comprehensive entry-level development platform for all of Microchip's 8-bit Flash PICs with 20 or fewer pins. Aimed at educators, students and newcomers to microcontrollers, the kit comes complete with five popular 8-bit PICs, along with a selection of discrete components, a PICkit 2 Debugger/Programmer and a CD containing a User's Guide, labs and application examples. The kit provides everything needed to quickly and easily develop applications using 8-bit PICs.

A solderless prototyping area on the development board allows users to explore a number of application examples described in the 'hands-on' labs from the PICDEM Lab User's Guide that comes with the kit. The easy-to-follow labs provide an intuitive introduction to common peripherals and then moves into a variety of application examples to reinforce core concepts.

All of the code examples are written in the high level programming language C, and can be compiled using the HI-TECH C compiler, available as a free download from www.microchip.com/HI-TECH.



The PICDEM Lab comes complete with the following:

- *PICDEM Lab development board, with samples of five 8-bit PICs*
- *Component kit*
- *PICkit 2 Debugger/Programmer*
- *CD containing comprehensive user's guide, labs and application examples.*

The PICDEM Lab Development Kit (part number DM163035) is available for $124.99. For more information, go to: **www.microchip.com/picdemlab**.

Pico's new waveforms

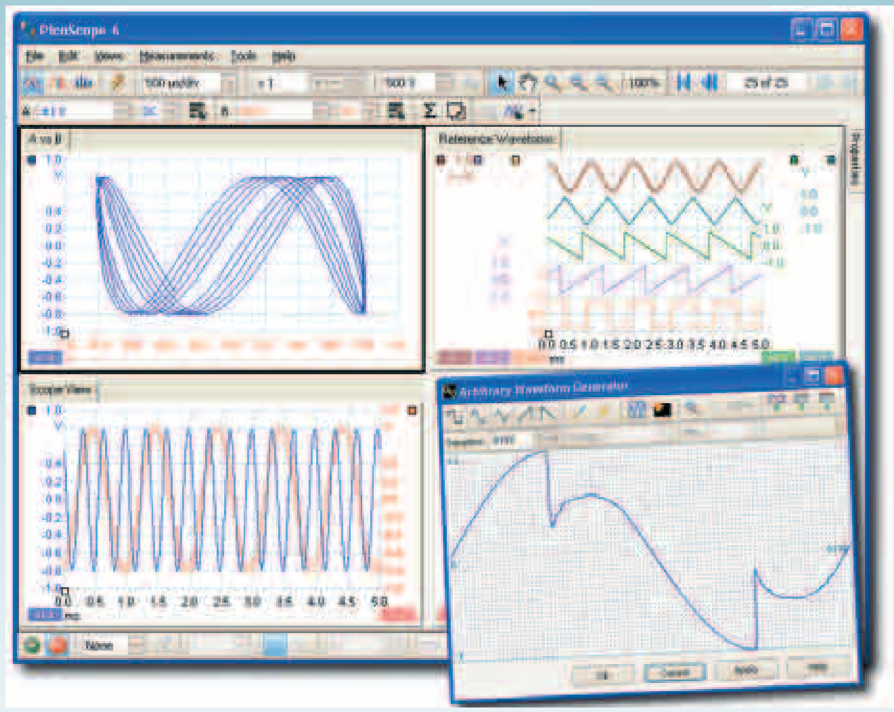
PicoScope, the PC Oscilloscope software from Pico Technology, is claimed to be one of the best-known oscilloscope packages on the market. Its carefully designed ergonomics and clear, uncluttered layout have set a benchmark for PC Oscilloscope displays. Now it's even more powerful, with a number of valuable features added to the latest beta release.

The Reference Waveforms feature allows you to display stored waveforms or math channels alongside live data. To add a reference waveform, just click a button and select which channel to store. You can build up as many as eight waveforms, reference or live, in each scope view, and you can open as many scope views as you need.

The other major new feature is XY Mode. This allows you to plot one or more input channels against another, or against a math channel or reference waveform.

Among the other improvements in this release is a new trigger mode. Rapid Mode captures a sequence of triggered waveforms, while freezing the display, and thus obtains the shortest possible dead time between captures.

Other significant new features are the graphical Arbitrary Waveform Editor, which lets you create, save, load and edit arbitrary waveforms for use with your PicoScope 2000 or 5000 Series scope; and support for Windows Vista 64-bit in addition to 32-bit XP and Vista.



Alan Tong, managing director of Pico Technology, explained: "You can download a free copy of PicoScope 6.2.1 on our website at **labs.picotech.com**. As always, we give free technical support and free updates to all our customers. Even if you don't have a Pico oscilloscope, you can still download the software and try it out."

THIRD INDUSTRIAL REVOLUTION

Michigan's Oakland University has launched a new nanotech institute, intending to lead the way for the world's third industrial revolution. Dr Virinder Moudgil, senior vice president for academic affairs and provost for Oakland University recently announced the launch of the new NanoTech Research & Development Institute.

Dr Moudgil believes Oakland University's nanotech initiative will contribute significantly to the emerging sector of science and technology with virtually limitless possibilities. By advancing the understanding and control of the fundamental building blocks of nature, this field of exploration is expected to lead to unprecedented breakthroughs in health care, energy, manufacturing, computer technology, agriculture and more. The NanoTech Institute will serve as the focal point of these breakthroughs.

One of the ultimate goals of nanotechnology is to create functional materials, devices and systems through the control of matters at nanoscale, which is at the atomic and molecular levels. The emerging fields of nanotechnology are leading to unprecedented understanding and control over the fundamental building blocks of all physical objects.

New Norton Utilities

Symantec is returning to its roots and releasing a new version of Norton Utilities, the PC maintenance program that Peter Norton offered before Symantec bought his company and discontinued Utilities as a standalone package six years ago. Symantec is also hoping to please hardcore gamers with a version of its Anti-Virus software that puts less load on a PC while gameplay is in progress.

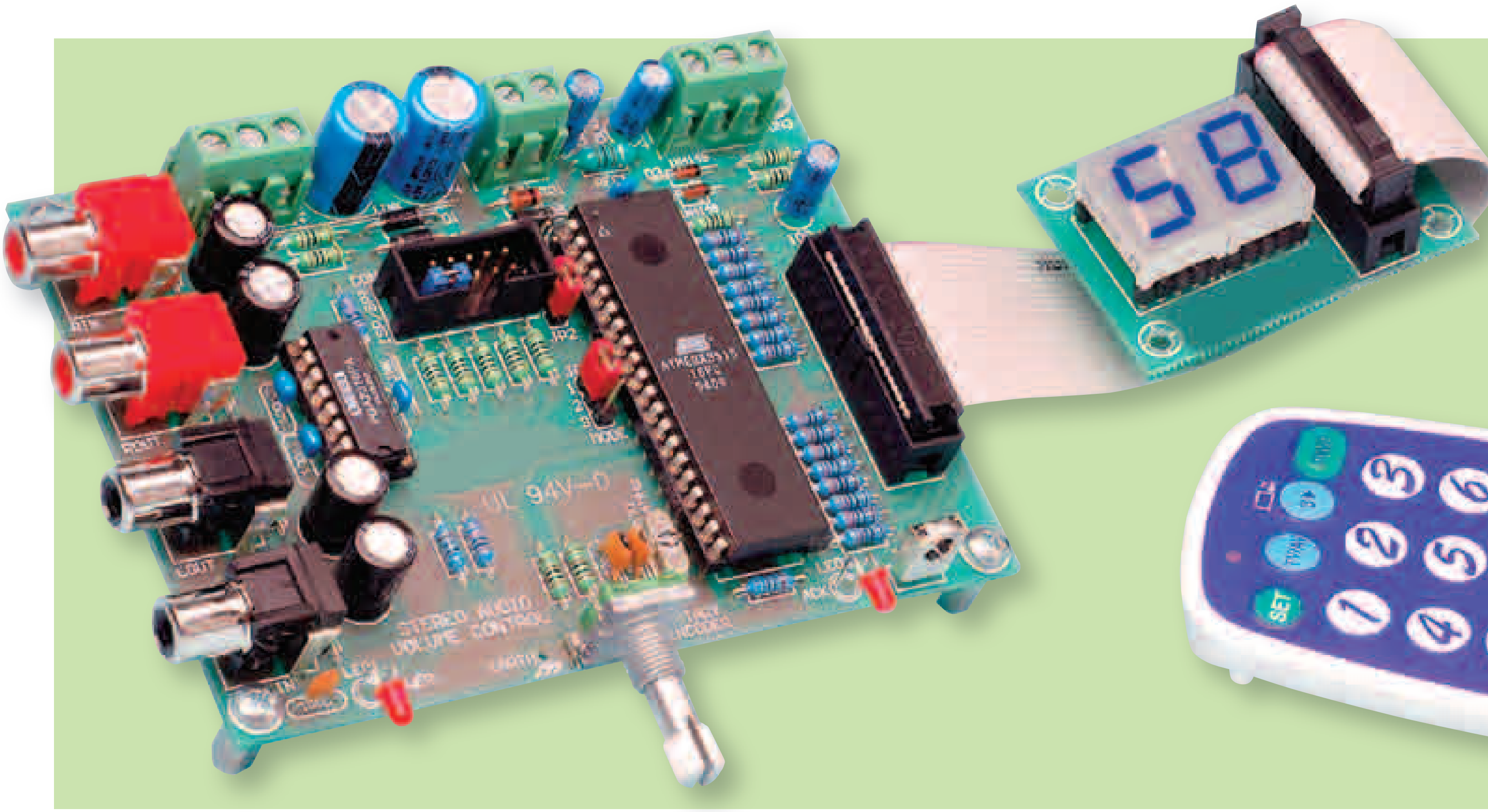
"In today's economic climate, we're all trying to do more with what we've already got," said Con Mallon, EMEA consumer director. With Norton Utilities, he says, Windows PCs that have been slowed by accumulated disk clutter and registry errors can now be given a new lease of life. For £40 the owner gets licences to activate the program on three PCs.

Symantec says pressure from hard-core gamers has prompted the release of Norton AntiVirus 2009 Gaming Edition, also priced at £40. "Gamers want protection, but do not want anything running in the background and sucking processing power", says Stefan Wesche, technical reviews manager EMEA. The new package does not scan and update while a game is playing; and if the gamer insists, protection can be suspended while a game is played.

"For some new games, like Crysis, you need a very high performance PC and some gamers do not want anything running in the background. Better to have no protection when you are gaming, and protection when you are surfing, than no protection at all" says Wesche. The on screen control panel has also been altered to make it look more like a game dashboard.

Symantec is now offering free support by chat, email or phone and pledges to make the options clearer to customers. Symantec now acknowledges that its home page has been defaulting to the US site, and thereby leading unwary users to a US telephone number and unnecessarily high support call charges.

Barry Fox



Remote Volume Control & Preamplifier Module

This up-to-date control module works with any universal infrared remote and features a blue LED readout and an optional rotary encoder. Its ability to both attenuate and amplify means that it can operate as a simple volume control or as a high-performance stereo preamplifier.

SINCE THE PUBLICATION of two Remote Volume Control modules (April '08 and Jan '09), using the same motorised dual-ganged potentiometer, a number of readers have requested a similar module with digital, rather than analogue, attenuation. In other words, they want to dispense with the potentiometer, citing the short operational life and poor channel-to-channel tracking of these mechanical components.

So here it is! Now you've no excuse not to do away with that claimed 'noisy old pot' and upgrade to this state-of-the-art digitally controlled module – which should, in theory, never wear out!

Main features

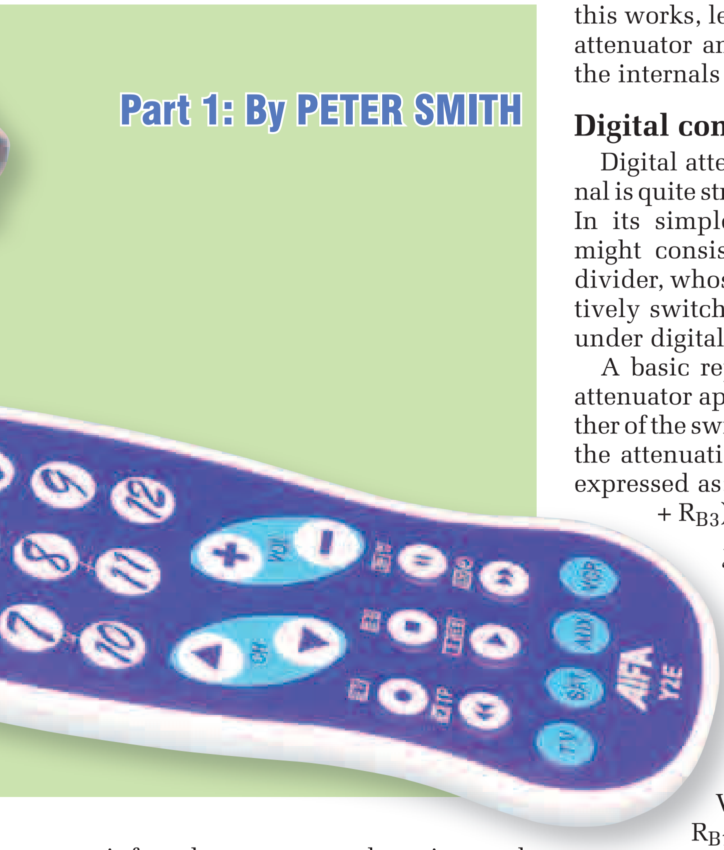
The Remote Volume Control & Preamplifier Module allows volume and balance adjustments to be made with any universal infrared remote control. Adjustments can also be made via an optional up-front rotary encoder. The encoder we've selected has 20 detents per revolution and a positive, professional feel.

The volume and balance levels are displayed on a blue or red two-digit readout, which can be set to 'go blank' shortly after each adjustment for less invasive operation. Muting is also supported via remote control.

Due to its universal nature, the module can be used in-line in just about any hifi audio system. For example, it could be inserted between your CD/DVD player and power amplifier.

The design is essentially a two-chip solution, with the audio side handled by a high-performance Burr-Brown PGA2310 stereo audio volume control IC. An Atmel ATmega8515 microcontroller manages the user interface, which comprises the rotary encoder, two optional selection switches, an

Part 1: By PETER SMITH



infrared remote control receiver and two seven-segment displays. It also communicates with the PGA2310 over a three-wire serial interface to set the device's volume levels.

The two displays mount on their own small PC board and are wired back to the module via ribbon cable. All other components mount on the main board, which is designed to fit directly behind the front panel of a metal enclosure. This arrangement affords flexibility and simplifies construction for the majority of case assembly options.

Power supply

Also featured is a new, low-noise power supply module, which includes its own on-board transformer. If the long slim board layout doesn't suit your case, then the PC board has been designed so that you can slice off the transformer and juggle the two modules about to your heart's content.

But wait – there's more! For those who already have a suitable chassis-mount transformer, we've also included a version of the supply without the transformer, to save you having to cut the board apart in the first place!

OK, so this new design uses a digital rather than analogue volume adjustment method. To understand how this works, let's look briefly at a basic attenuator and then compare this to the internals of the PGA2310.

Digital control

Digital attenuation of an audio signal is quite straightforward in concept. In its simplest form, an attenuator might consist of a resistive voltage divider, whose elements can be selectively switched in and out of circuit under digital control.

A basic representation of such an attenuator appears in Fig.1. With neither of the switches (S1 and S2) closed, the attenuation of the circuit can be expressed as: $V_{OUT}/V_{IN} = (R_{B1} + R_{B2} + R_{B3})/(R_A + R_{B1} + R_{B2} + R_{B3})$.

Applying a digital logic 'high' level to the control input of either switch causes it to close, bypassing a branch of the string. For example, if S1 closes, resistors R_{B2} and R_{B3} are bypassed, so the expression becomes: $V_{OUT}/V_{IN} = R_{B1}/(R_A + R_{B1})$.

As you can see, the circuit has three possible states or levels of attenuation. To increase the number of states, it's just a matter of adding more resistors and switches. For audio use, the resistor values would be chosen so that each state change results in a logarithmic change in the attenuation level.

Why the op amp? It acts as a buffer, isolating the circuit from output loading effects and generating a constant output impedance regardless of attenuation level.

Programmable gain

As mentioned, this design is based around the PGA2310 IC from Burr-Brown (Texas Instruments) – see Fig.4. It integrates a digitally programmable attenuator that operates in much the same way as our example in Fig.1. However, this device is a little different in that the gain of its op amp is also digitally programmable.

This means that it can be programmed to operate as an attenuator or an amplifier. Its overall adjustment span is 127dB, ranging from –95.5dB to +31.5dB in 0.5dB steps. Gain changes are effected during audio signal zero crossings, eliminating the audible 'clicks' that typically occur without this feature.

Two identical channels are included, labelled (not surprisingly) 'left' and 'right'. The level of each channel is set by a 16-bit serial data word that is transferred via the device's digital interface. The PGA2310 was designed specifically for professional audio work, boasting high dynamic range and very low noise and distortion.

How it works

We've endeavoured to keep construction as simple as possible, hence the use of just three ICs (see Figs.2 and 3). The microcontroller (IC2) handles all aspects of the user interface, which comprises the rotary encoder, infrared receiver IC3, the LED displays and pushbutton switches S1 and S2. In response to user commands, the micro (IC2) sends the desired volume level to the volume control chip (IC1) via a 'three-wire' serial interface.

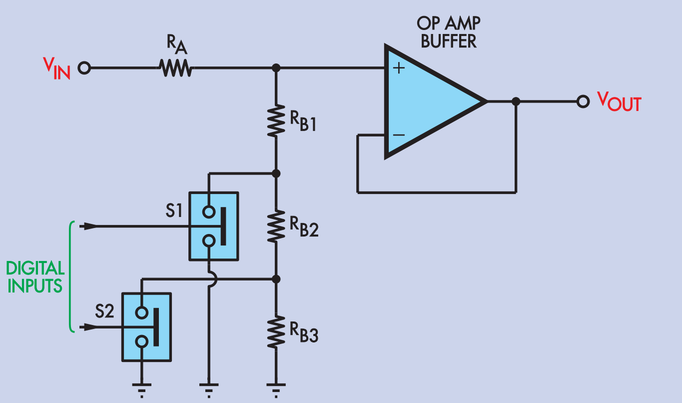
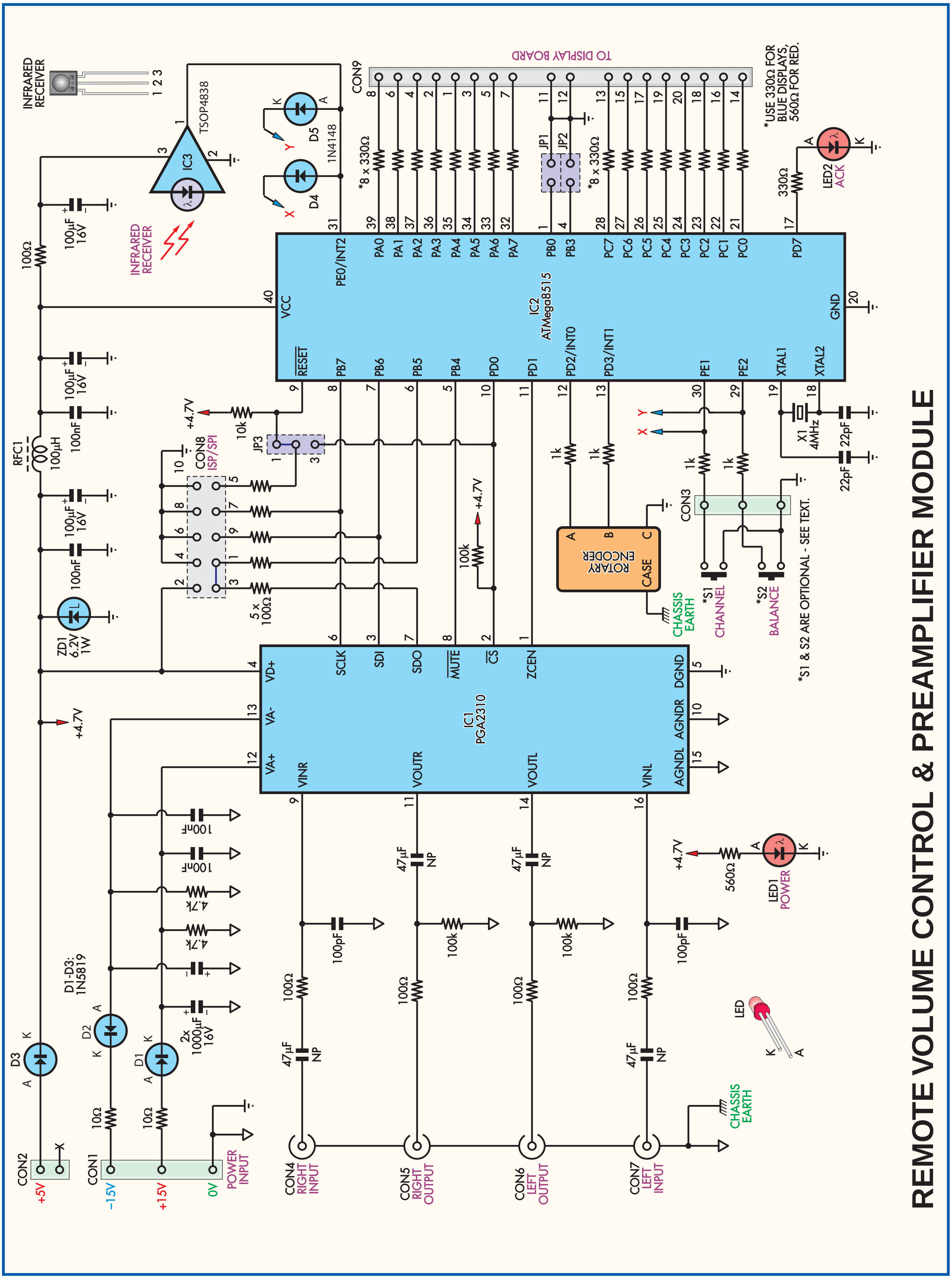


Fig.1: this simplified circuit represents the basics of a digitally-controlled analogue attenuator. Two analogue switches (S1 and S2) are opened and closed under digital control to select the input-to-output attenuation level of the circuit.



REMOTE VOLUME CONTROL & PREAMPLIFIER MODULE

Fig.2: the complete circuit diagram for the module, minus the display board. All analogue functions are handled by the PGA2310 volume control chip (IC1), while microcontroller IC2 deals with the user interface. When a volume change is requested by the user – either via the infrared receiver (IC3) or the rotary encoder – the microcontroller interprets the request and sends the new data down a serial pipe to IC1.

The serial interface consists of the signal lines SDI (Serial Data In), SDO (Serial Data Out), SCLK (Serial Clock) and CS (Chip Select). Each serial data transfer from the micro to the PGA2310 (IC1) consists of a complete 16-bit word, comprising one byte for each channel. Those interested in the specific timing details will find them in the relevant datasheet, available from Texas Instruments at: **www.ti.com**.

The micro (IC2) can immediately mute both channels by driving the MUTE input of IC1 low. It can also determine how a new gain setting is applied to the device's control registers by controlling the ZCEN input. If this input is high, the gain is updated on the second zero crossing of a channel's input signal. This minimises audible glitches on the output. Conversely, if ZCEN is low, the update is performed as soon as it's received.

Note that with high volume levels and no input signal, it may well be possible to hear clicks when altering the volume level. This occurs because the PGA2310 waits only 16ms for the two zero crossings and if not detected, the new gain setting will take effect with no attempt to minimise audible artifacts.

Analogue side

The analogue interface side is extremely simple, consisting of just a handful of resistors, capacitors and RCA phono sockets (CON4 to CON7). The left and right channel inputs are arranged so as to be as far apart as practically possible, with obvious benefits in the channel crosstalk performance (see performance panel).

As shown, the signal inputs are capacitively coupled to prevent DC currents from flowing in the PGA2310's attenuator circuits. The 100Ω series resistors provide a small amount of protection from input over-voltages and also interact with 100pF capacitors to ground to filter out high-frequency noise. Note that larger resistor values cannot be used here because they would degrade the PGA2310's distortion performance.

On the output side, 100Ω resistors isolate the PGA2310's drivers from cable and amplifier input capacitance, thereby ensuring stability. They also provide a measure of protection from short-circuit signal lines. Again, coupling capacitors prevent DC currents flowing in the output circuit.

Keeping noise at bay

Apart from minimising external logic, the use of a large 40-pin microcontroller also allowed us to dispense with the need for display multiplexing, as each LED segment can be driven by one port pin. This is an important element of the design, because it eliminates a potential source of switching noise.

The other area that requires careful design to keep noise at bay is the power supply. As you can see in Fig.2, we've used *RC* filters comprising 10Ω resistors and 1000µF capacitors on the ±15V rails to reduce noise to a minimum. Strictly speaking, these are not required when the module is powered from the supply described here. However, they ensure consistent performance if the

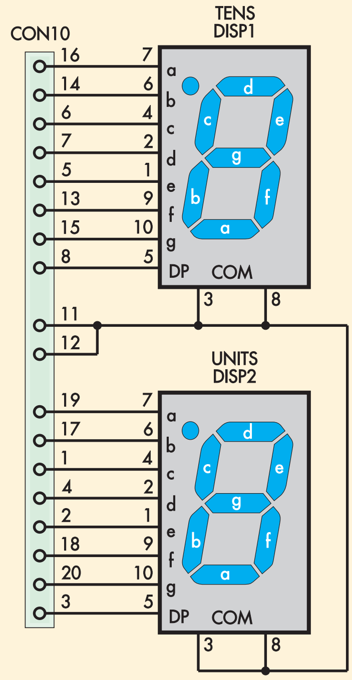


Fig.3: there's not a lot to the display board – just two common-cathode seven-segment displays and a 20-way header socket. Resistors in series with each segment (on the main board) limit LED current to less than 5mA; an important requirement, as I_{OH} current for ports A and C must not exceed 100mA in total.

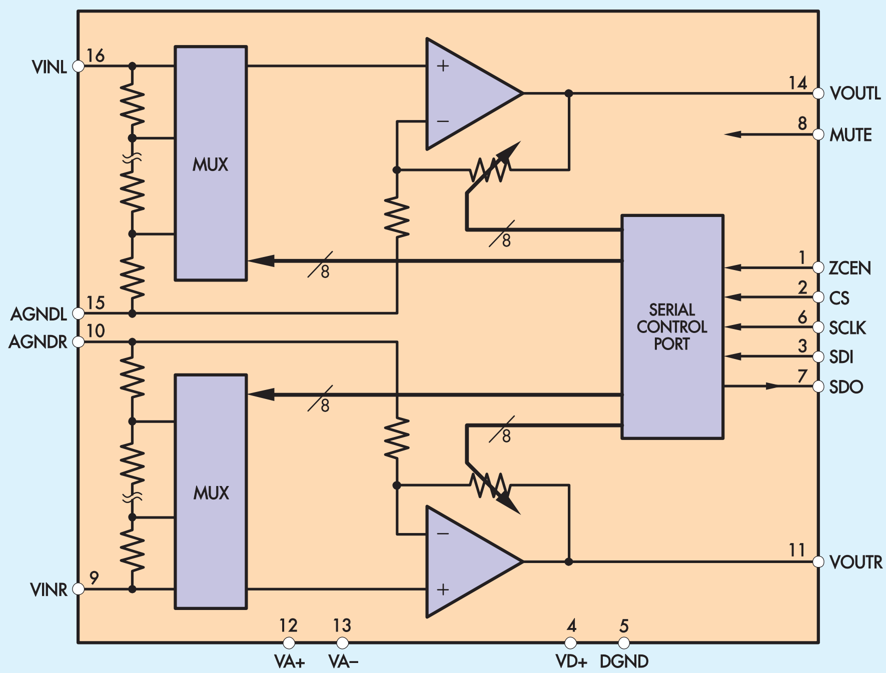


Fig.4: this block diagram shows the internal functions of the PGA2310 volume control IC. Both the input attenuation level and op amp gain are digitally controlled. The attenuation/gain levels are set via the on-board serial control port logic, which receives its data from the microcontroller.

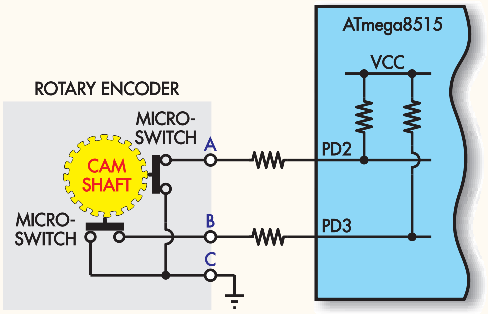


Fig.5(a): a basic representation of a rotary encoder. This also shows how the switch inputs are pulled up via resistors internal to the microcontroller. The programme in the micro filters out switch contact bounce and interprets the 'A' and 'B' signals to detect shaft rotation and direction.

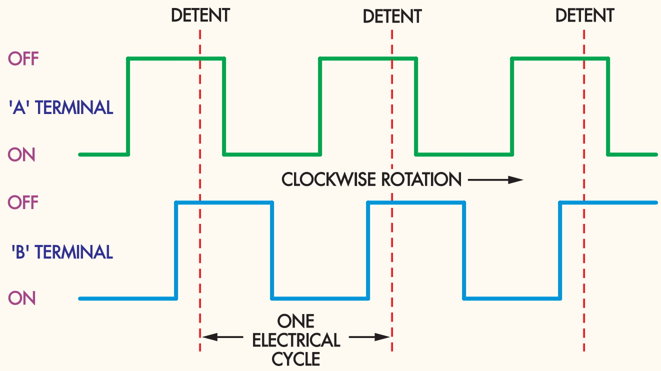


Fig.5(b): the two out-of-phase switch signals from the rotary encoder generate a two-bit Gray code, defining one complete electrical cycle. Some encoders will have more than one detent per cycle

unit is to be powered from the auxiliary outputs of a power amplifier's supply, for example.

Conducted noise from the microcontroller is reduced by the inclusion of an *LC* filter in its 4.7V supply, made up of a 100µH choke (RFC1) and an associated 100µF capacitor. In addition, digital ground is connected to analogue ground at one point only – ie, at the power input connector (CON1).

To ensure that this strategy is effective, you **must** use heavy-duty hook-up wire for the power supply wiring, as described in Part 2 next month.

Protection

Schottky diodes (D1 to D3) in series with all inputs help to reduce the chances of blowing something up if the input wiring is accidentally reversed. With the excellent dynamic range of the PGA2310, the loss of 300mV or so in the supply rails has little effect on performance.

Despite this protection, it's still possible to make a mistake – such as feeding +15V into the +5V input. In this case, Zener diode ZD1 will conduct and rapidly collapse the rail, while sending up smoke signals. Assuming that you spot these early on, disaster may well be averted!

Performance

- Frequency response ....flat from 10Hz to 150kHz
- Maximum input signal .... 9.7V RMS (0dB gain), 250mV RMS (+31.5dB gain)
- Input impedance .... ~10kΩ
- Output impedance 100Ω
- Harmonic distortion .... typically 0.002% (see Fig.9)
- Signal-to-noise ratio ....–120dB (20Hz to 22kHz bandwidth)
- Channel crosstalk ....–126dB @ 1kHz, –123dB @ 10kHz
- Adjustment range......... 127dB (–95.5dB attenuation to +31.5dB gain)
- Step size.............................. 0.5dB or 1.5dB (selectable)
- Gain matching .... ±0.05dB
- Display resolution............................... 1.5dB

Note: except where indicated, all measurements were performed with a 600mV RMS input signal at 0dB (unity) gain with the output driving a 50kΩ load. For crosstalk measurements, the non-driven input was back-terminated into 600Ω.

No special interface logic is required for the switches or rotary encoder, because the entire switch debouncing and decoding sequence is carried out in firmware. The same applies to the output of the infrared receiver module (IC3). Its serial data stream is interpreted in line with the Philips RC5 infrared protocol, using an accurately timed, high-speed sampling algorithm to ensure excellent long-range performance.

Encoder basics

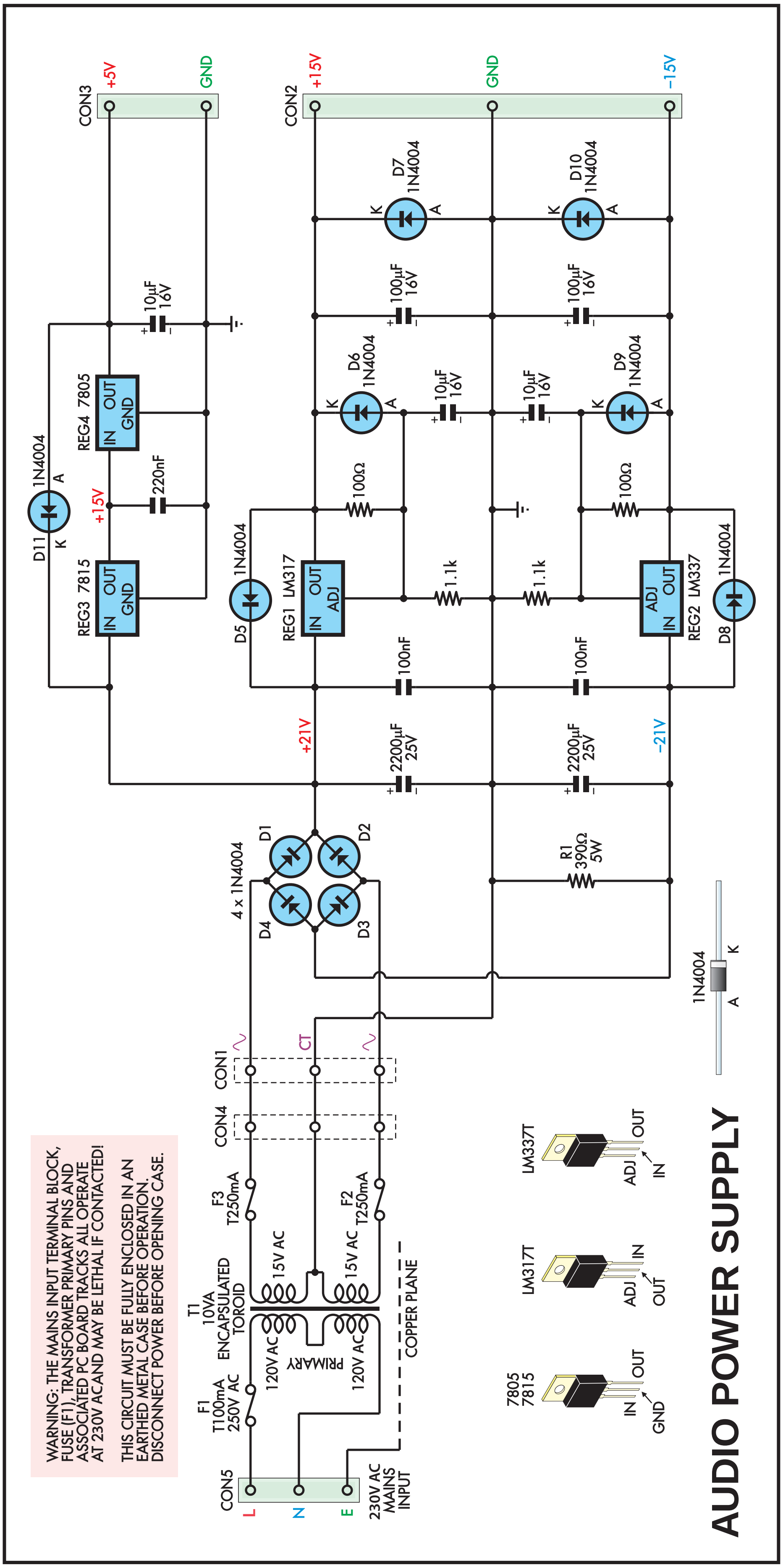
If you've never used a rotary encoder, you may be wondering how they work. The simplest encoders consist of a multi-lobed cam that is used to operate two microswitches (Fig.5a).

When the shaft connected to the cam is rotated, one of the switches opens and closes in advance of the other, depending on the direction of rotation. This generates a two-bit Gray code at the switch output terminals, which can be interpreted by a microcontroller or other digital logic to determine shaft position and direction of rotation (see Fig.5b).

As you can see, the four Gray code states describe one complete cycle, with the detents occurring when both switches are off. The encoder used in this project has 20 cycles (or 'pulses') and detents per revolution, so the cycle repeats every 18° of rotation. Its direction of travel is indicated by the phase of the two signals, which are always 90° apart.

The timing diagram applies to most two-bit encoders that utilise one detent

Fig.6: the low-noise power supply uses common three-terminal regulators and features an on-board toroidal transformer. This transformer generates less radiation than larger chassis-mounted units, so it should be possible to build the whole lot into a relatively small case without having problems with induced mains noise.



per cycle (equal pulses and detents per revolution). In fact, the microcontroller program expects this configuration, so if you're thinking of sourcing an alternative part, be sure that it meets this criteria. Also, get a unit with 20 or more detents – any less will result in unnecessary knob winding!

Many other configurations are available; two and four detents per cycle are common. For example, an encoder specified with four cycles/rev and 16 detents/rev has four detents/cycle and is unsuitable for use here – it would take four clicks (1/4 revolution) to make a single change to the volume or balance!

Note also that some encoders have built-in switches. Such a device would be ideal for this project, because it would be possible to wire the BALANCE switch input (at CON3, Fig.2) to the encoder's switch terminals, thereby dispensing with the need for a separate switch to select balance adjustment mode.

Low-noise power supply

To ensure the best possible performance, we've designed a separate, low-noise power supply to match the Remote Control & Preamp module. It provides regulated ±15V and +5V outputs and could be used with a variety of other audio projects. As mentioned earlier, it even includes an on-board toroidal transformer to further simplify construction.

As shown on the circuit diagram (Fig.6), the transformer's two 15V AC secondary windings are connected in series to form a 30V AC centre-tapped configuration. Note the fuses in the secondary outputs – these are included because the voltage regulators' built-in current limiting may be too high to protect a small 10VA transformer in the event of an output overload.

Diodes D1 to D4 and two 2200 F capacitors rectify and filter the

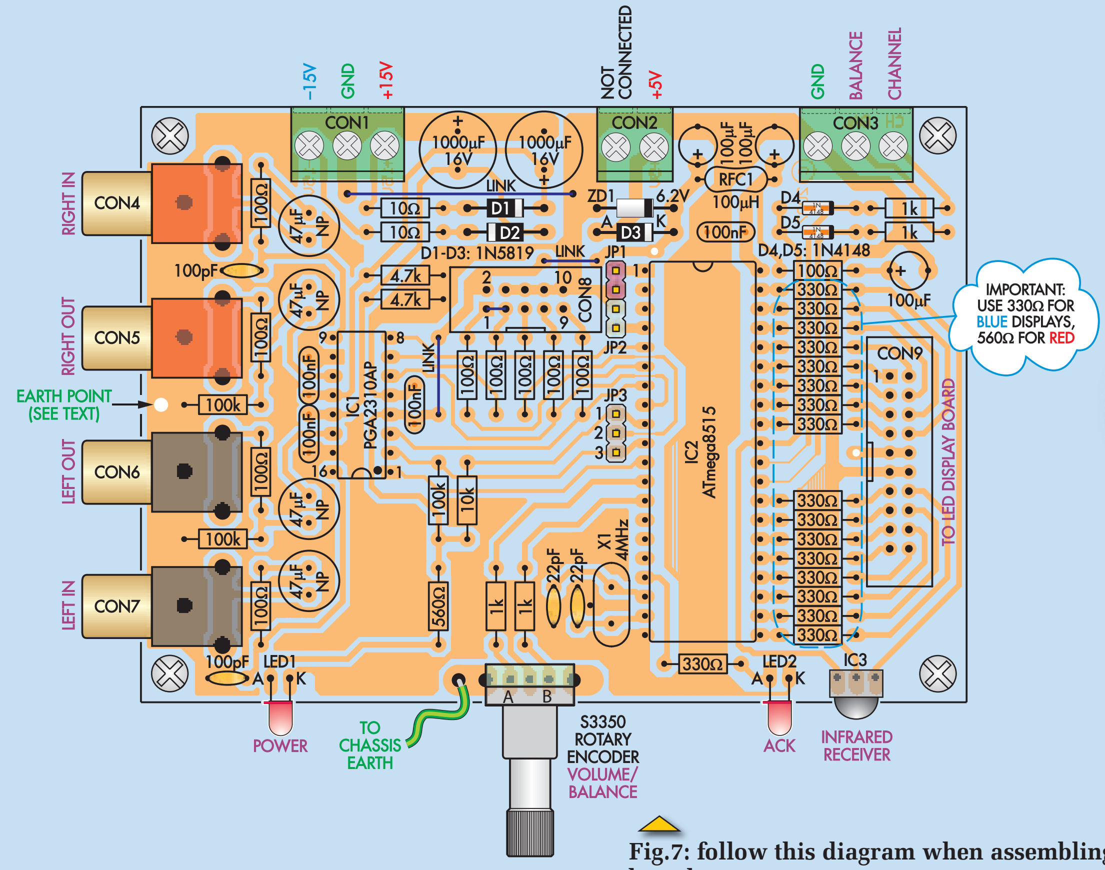


Fig.7: follow this diagram when assembling the control board.

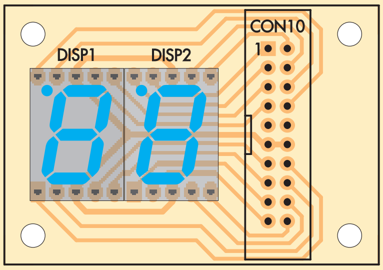
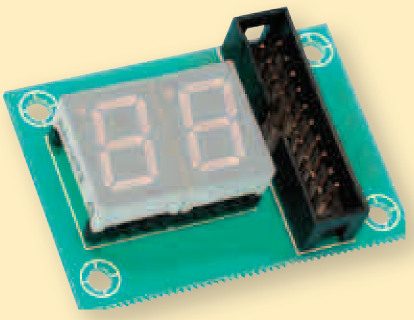


Fig.8: it should only take a few minutes to assemble the display board. Note how the decimal points go at the top of the read-outs, rather than at the bottom.



This is the completed display PC board assembly. The LED readouts plug into two single in-line header strips.

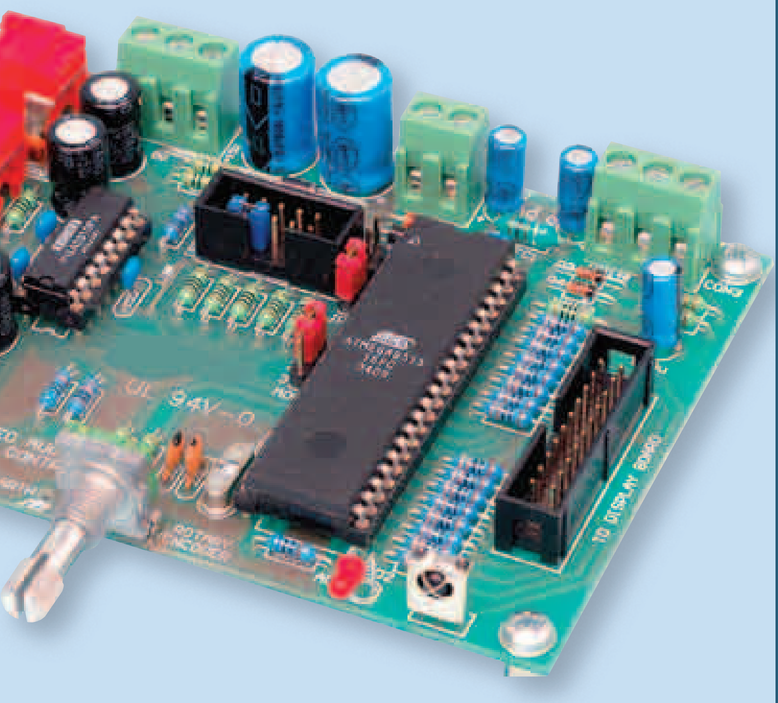
secondary output to create ±21V DC (nominal) rails. The following LM317 and LM337 adjustable regulators then generate the complementary positive and negative supply rails. Their outputs are programmed to ±15V by virtue of the 100Ω and 1.1kΩ resistors connected to their 'OUT' and 'ADJ' terminals.

We've used adjustable regulators in this design because the ADJ terminals can be bypassed to ground to improve ripple rejection, which we've done using 10µF capacitors. The associated diodes (D6 and D9) provide a discharge path for the capacitors should an output be accidentally shorted to ground. Two reverse-connected diodes (D7 and D10) across the output prevent their respective rails from being driven to the opposite polarity (for example, if a regulator fails).

A 7805 3-terminal regulator (REG4) is used to generate the +5V rail. To reduce power dissipation in REG4, a second fixed regulator (REG3) is positioned 'upstream' to reduce the DC

Table 1: Resistor Colour Codes (Control Board)

❑	Value	4-Band Code (1%)	5-Band Code (1%)
❑	100kΩ	brown black yellow brown	brown black black orange brown
❑	10kΩ	brown black orange brown	brown black black red brown
❑	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	1.1kΩ	brown brown red brown	brown brown black brown brown
❑	1kΩ	brown black red brown	brown black black brown brown
❑	560Ω	green blue brown brown	green blue black black brown
❑	330Ω	orange orange brown brown	orange orange black black brown
❑	100Ω	brown black brown brown	brown black black black brown
❑	10Ω	brown black black brown	brown black black gold brown



Watch the orientation of the diodes, IC sockets, polarised capacitors and shrouded headers (CON8 and CON9). Use only the resistor values specified for the LED displays – lower values could lead to damage to the microcontroller ports.

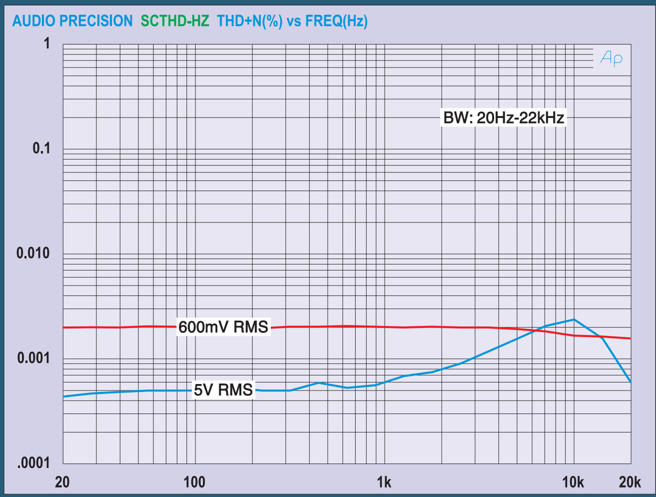


Fig.9: the noise and distortion sits at around 0.002% with a 600mV input signal. The datasheets quote a smaller THD+N figure, but use a much larger input signal – so we've plotted a second line to show the difference with a 5V input signal.

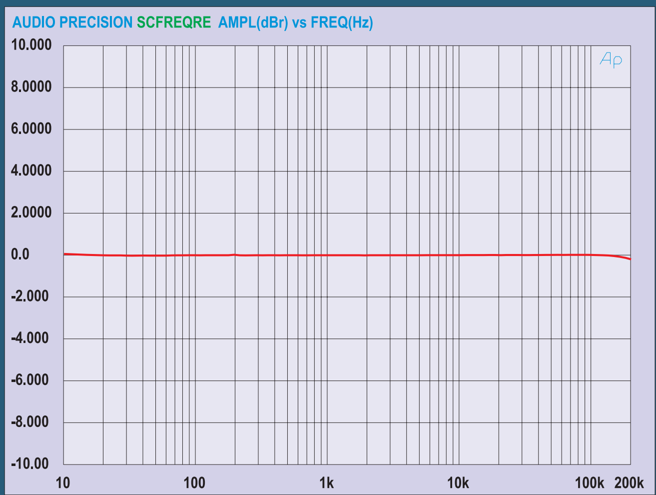


Fig.10: the frequency response is – well – flat!

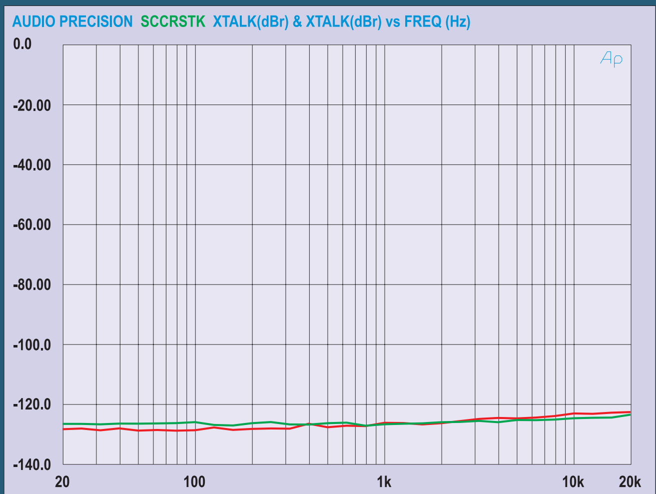


Fig.11: channel-to-channel crosstalk could hardly be better. The left and right signal inputs are located at opposite ends of the chip – and we took maximum advantage of this in the PC board layout.

input from 21V to 15V. While we could have just added a series resistor or even a transistor-based pre-regulator to achieve similar results, this arrangement is inexpensive and includes the regulator's protection features in the event of an overload.

Because the +5V supply draws power from only the positive side of the unregulated DC rail, a 390Ω 5W resistor (R1) across the negative input is included to help balance the rails, so that they decay at similar rates at power off.

Construction

We'll assemble the main PC board (code 714) first – see Fig.7. Begin by installing the three wire links using 0.7mm tinned copper wire, then install the resistors. Note that the 330Ω resistor values adjacent to CON9 on the overlay diagram are for blue displays only. If you've decided to use red displays instead, then substitute 560Ω values for 16 of the 330Ω parts, as indicated.

All of the diodes (D1 to D5 and ZD1) can go in next, taking care to orient their cathode (banded) ends as shown. That done, all remaining components can be installed in order of height, with attention to the following points:

- Be sure to insert the 1000µF and 100µF electrolytic capacitors the right way round, following the '+' markings on the overlay. The 47µF units are non-polarised and can go in either way.
- The notch in the IC sockets must match that shown on the diagram, as must the polarising notch in the two

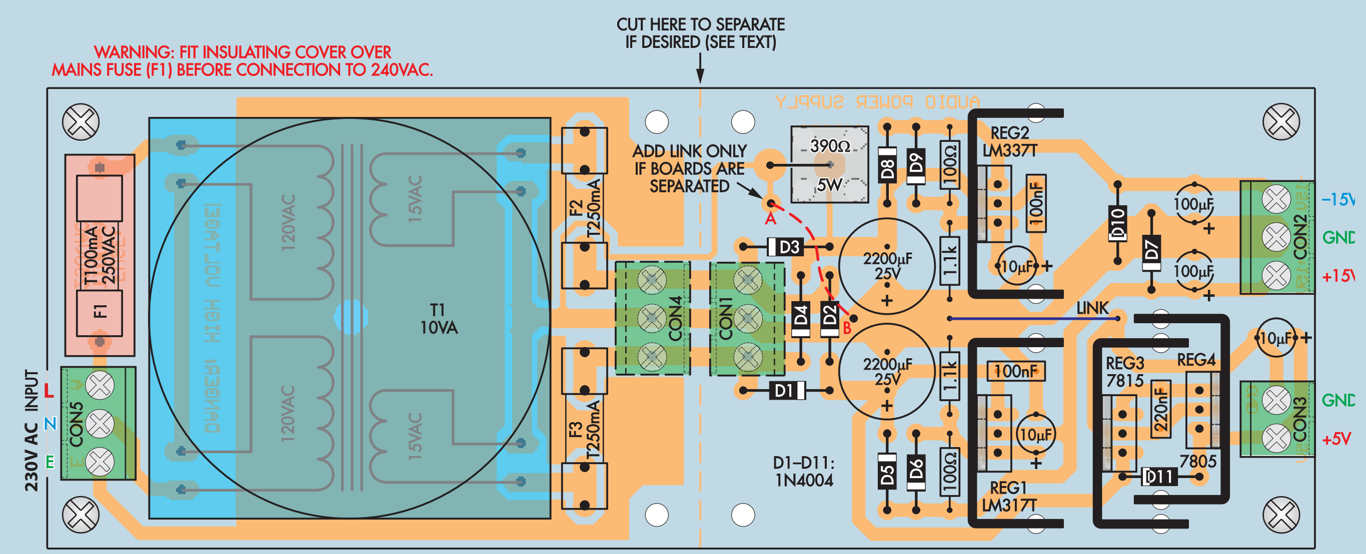


Fig.12a: follow this diagram when assembling the power supply board. Most constructors will not want to cut the board into two sections, so terminal blocks CON1 and CON4 won't be required. The transformer should be secured to the PC board via the central mounting hole before its pins are soldered.

Below: this view shows the fully-assembled power supply board. Don't forget to fit the cover over the mains fuse.

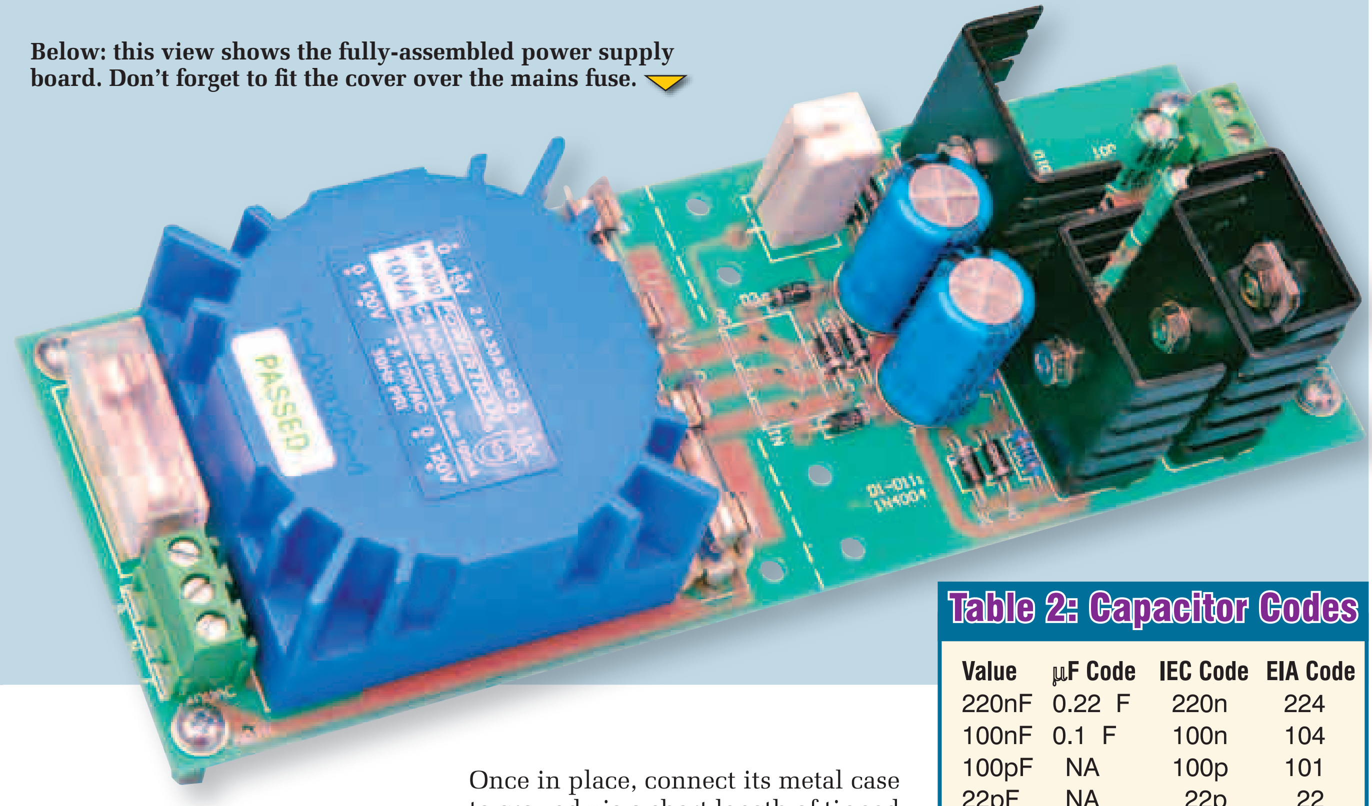


Table 2: Capacitor Codes

Value	µF Code	IEC Code	EIA Code
220nF	0.22 F	220n	224
100nF	0.1 F	100n	104
100pF	NA	100p	101
22pF	NA	22p	22

shrouded headers (CON8 and CON9). Do not plug the ICs into their sockets until after the power supply has been cabled in and tested (see the 'Testing' section in Part 2 next month).

- The terminal blocks (CON1 to CON3) and RCA connectors (CON4 to CON7) must be seated squarely on the PC board surface before soldering.
- Seat the crystal (X1) all the way down on the board before soldering. Once in place, connect its metal case to ground via a short length of tinned copper wire (see photo).
- The lead length and bend of the two LEDs and infrared receiver (IC3) can be determined by trial fitting the assembly into its intended position.

Display board

There's not a lot to the display board (PCB code 715) – just a socket for the two displays and a 20-way header (see Fig.8). The socket can be made by cutting down a longer single-in-line (SIL) header strip into two 10-pin sections. Make sure these are sitting perpendicular to the PC board before soldering.

When plugging in the display modules, note that the decimal points go at the top, not the bottom of the readout. Also, make sure that you've got the polarising notch of the header (CON10) facing inwards towards the displays.

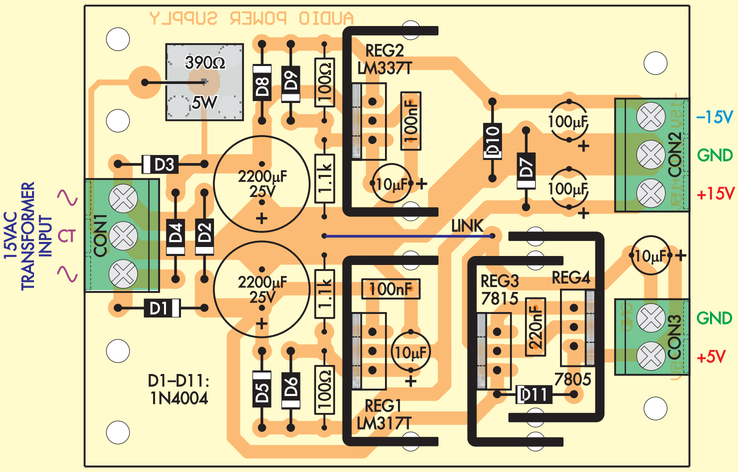


Fig.12b: this alternative version of the power supply board is available for those who prefer to use a chassis-mounted toroidal transformer.

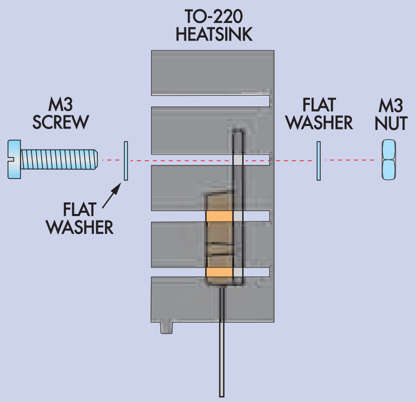
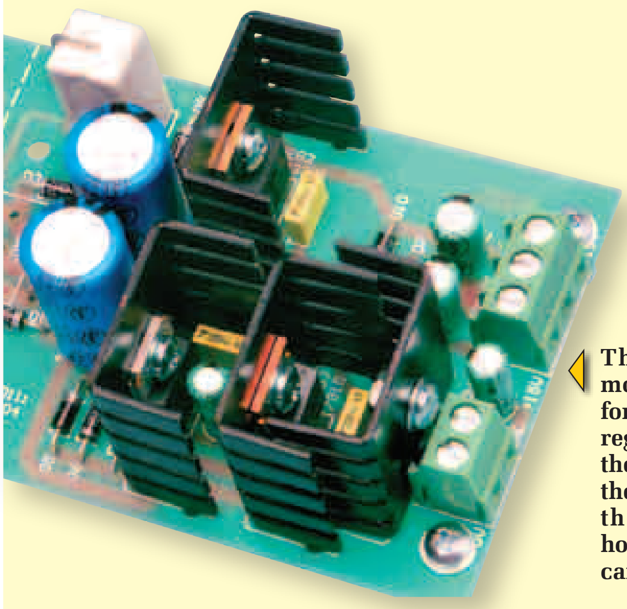
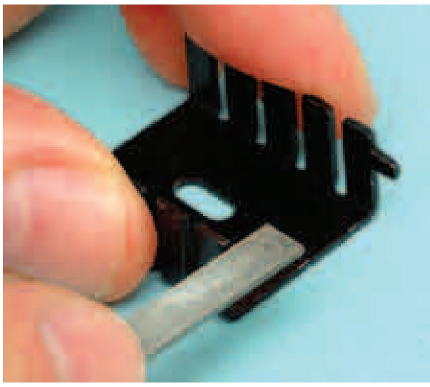


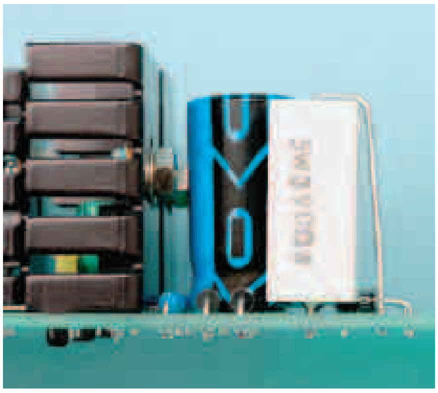
Fig.13: here's how to assemble the regulators to their heatsinks. The 7805 regulator (REG4) presents a special case; its screw should be inserted from the opposite side to that shown so that the screw head isn't obscured by REG3's heatsink.



This view shows the mounting arrangements for the heatsinks and the regulators at one end of the PC board. Be sure to fit the heatsink tabs through their matching board holes, so that the heatsinks cannot touch each other.



The PC board holes for the heatsink tabs should be drilled to 2.5mm. If this proves to be marginally too small to accept the tabs, you can use a jeweller's file to remove just enough of the tabs to get a neat fit.



The 390Ω 5W resistor should be mounted about 2mm off the PC board.

Power supply

The power supply (PCB code 716) can be constructed in a number of different ways. If you've elected to build the version with an on-board transformer, then you have the option of separating the transformer section from the remainder of the board before commencing construction (see Fig.12a). Most constructors will not need to do this – check your chassis layout for compatibility before reaching for a hacksaw!

If you are using a chassis-mounted transformer, then you may optionally choose the second (smaller) power supply board, which omits the on-board transformer, fuses and associated connectors (Fig.12b). However, the following text assumes that you are assembling the on-board transformer version.

As before, install all of the low-profile components first, starting with the single wire link.

Note that we've specified a single-piece fuseholder assembly with cover for the mains fuse (see parts list) – so be sure to fit this in the correct (F1) position. The other two fuses (F2 and F3) use low-cost fuse clips. Position the small retaining lug on each clip towards the outer (fuse end) side; otherwise proper fuse installation will be impossible.

The 390Ω 5W resistor mounts vertically (see photos) and should

Parts List – Remote Volume Control and Preamplifier

Main Control Board and Display

★1 main PC board, code 714, size 109 × 78mm
★1 display PC board, code 715, size 49mm × 34mm
1 rotary encoder, 20 pulses/detents per rotation (optional, see text)
1 2-way 5mm/5.08mm pitch terminal block (CON2)
2 3-way 5mm/5.08mm pitch terminal blocks (CON1, CON3)
1 10-way keyed boxed IDC header (CON8) (Jaycar PP-1100)
2 20-way keyed boxed headers (CON9, CON10)
2 PC-mount RCA phono sockets, red insert (CON4, CON5)
2 PC-mount RCA phono sockets, black insert (CON6, CON7)
1 40-way or 2 x 32-way 2.54mm SIL header socket(s)
1 7-way 2.54mm SIL header (JP1 to JP3)
3 jumper shunts
1 100mH choke (RFC1)
1 16-pin gold-plated IC socket
1 40-pin IC socket
4 M3 x 6mm pan head screws
4 M3 x 10mm tapped spacers
0.7mm diameter tinned copper wire for links

Semiconductors
★★1 PGA2310PA stereo volume control IC (IC1) (Farnell 121-2339)
1 ATmega8515-8P (or –16P) microcontroller (IC2) progr-ammed with DAVOL.HEX
★1 TSOP4838 (or equivalent) infrared receiver module (IC3) (Jaycar ZD-1952, Farnell 491-3190)
1 4MHz crystal, HC49S package (X1)
3 1N5819 Schottky diodes (D1 to D3)
2 1N4148 small-signal diodes (D4, D5)
1 1N4735A 6.2V 1W Zener diode (ZD1)
2 127mm common-cathode 7-segment LED displays, blue or red
2 3mm red LEDs (LED1, LED2)

Capacitors
2 1000µF 16V PC radial elect.
3 100µF 16V PC radial elect.
4 47µF 35V/50V non-polarised PC radial elect. (max. 8mm dia.)
4 100nF 50V monolithic ceramic
2 100pF ceramic disc
2 22pF ceramic disc

Resistors (0.25W 1% carbon or metal film)

3 100kΩ	16 560Ω (red displays)
1 10kΩ	1 330Ω
2 4.7kΩ	16 330Ω (blue displays)
4 1kΩ	10 100Ω
1 560Ω	2 10Ω

Additional items
2 20-way IDC cable-mount sockets
20-way IDC ribbon cable
Pushbutton switch (optional – see text) (S1, S2)
Universal remote control (see text)

Power Supply

★1 PC board, code 716, size 168 × 61mm (on-board transformer)
–or-
1 PC board, cut from 716, size 80 × 61mm (off-board transformer)
4 Micro-U 19°C/W TO-220 heatsinks with tabs
2 3-way 5mm/5.08mm terminal blocks (CON1, CON2)
1 2-way 5mm/5.08mm terminal block (CON3)
4 M3 × 10mm tapped spacers
8 M3 × 6mm pan head screws
4 M3 nuts and flat washers
0.7mm diameter tinned copper wire for link
Heavy-duty hook-up wire for low-voltage wiring
Heatsink compound

Semiconductors
1 LM317T adjustable positive regulator (REG1)
1 LM337T adjustable negative regulator (REG2)
1 7815 +15V regulator (REG3)
1 7805 +5V regulator (REG4)
11 1N4004 400V 1A diodes (D1 to D11)

Capacitors
2 2200µF 25V 105°C PC radial electrolytic
2 100µF 16V 105°C PC radial electrolytic.
3 10µF 16V 105°C PC radial elect.
1 220nF 50V metallised polyester
2 100nF 50V metallised polyester

Resistors (0.25W 1%, except R1)
2 1.1kΩ
2 100Ω
1 390Ω 5W 5% (R1)

Additional items for on-board transformer version
1 15V+15V 10VA PC mounting toroidal transformer
1 M205 250V AC PC-mount fuseholder w/cover (F1)
4 M205 fuse clips (F2, F3)
2 3-way 5mm/5.08mm terminal block (CON4, CON5)
1 100mA 250V AC M205 slow-blow fuse (F1)
2 250mA M205 slow-blow fuses (F2, F3)
Self-tapping screw for transformer mounting
Mains connection hardware to suit

sit about 2mm proud of the PC board surface to aid in cooling. If the board has been cut into two parts, then you'll need to run an insulated wire link between points 'A' and 'B' to reconnect the ground end of this resistor back into circuit. On a similar note, terminal blocks CON1 and CON4 need only be installed if the board was cut apart.

Due to its size and weight, the transformer must be firmly attached to the board using an appropriate self-tapping screw via the provided mounting hole before its pins are soldered. If this is done in reverse order, the PC board pads may delaminate – you have been warned!

Leave the four regulators (REG1-REG4) until last. These must be attached to TO-220 finned heatsinks before being installed on the PC board. First, smear a thin film of heatsink compound to both the rear (metal) area of each device, as well as the mating areas of the heatsinks. That done, fasten them to the heatsinks using M3 screws, nuts and washers as shown in Fig.13, but don't fully tighten the screws just yet.

Additional items for off-board transformer version
1 15V+15V 20VA (or larger) toroidal transformer
Mains connection hardware to suit

Notes

Note 1: the low-voltage version of the microcontroller is also compatible with this project and is available from Futurlec at www.futurlec.com.au, part number ATmega8515L-8PI (or –8PU).

Note 2: The program file (DAVOL.HEX) will be available from the *EPE* website (www.epemag.com) for those who wish to program their own microcontrollers.

Ready programmed microcontrollers are available from Magenta Electronics – see their advert in this issue.

Note 3: to avoid assembly difficulties and ensure long-term reliability, all the three-terminal regulators (REG1-REG4) used in the power supply should be recognised name-brand devices, such as On Semiconductor/Motorola, STMicroelectronics, National Semiconductor or Fairchild.

*www.jaycarelectronics.co.uk
** www.farnellinone.com
★ Printed circuit boards available as a set from the *EPE PCB Service*

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Universal infrared remote controls

The volume control module is designed to work with most universal ('one-for-all') infrared remotes. It recognises the RC5 protocol that was originally developed by Philips, so the remote must be programmed for a Philips (or compatible) appliance before use.

Most universal remotes are provided with a long list of supported appliances and matching codes. To set the remote to work with a particular piece of gear, it's usually just a matter of entering the code listed for the manufacturer (in this case, Philips), as detailed in the instructions.

You'll also notice that different codes are provided for TV, CD, SAT, and so on. This allows two or more appliances from the same manufacturer to be operated in the same room and even from the same handpiece.

This multiple addressing capability can be useful in our application, too. Normally, we'd program the remote to control a TV, as this works with the control module. But what if you already have a Philips TV (or a Chinese model that uses the RC5 protocol)? Well, in this case, you'd simply use a CD or SAT code instead – the control model can handle any or these!

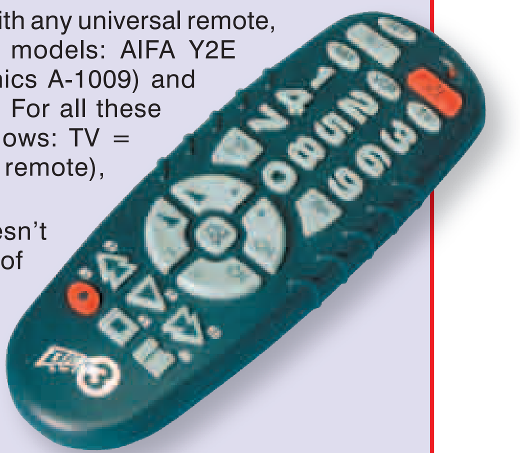
Let's look at an example. To set the AIFA Y2E remote to control a Philips TV, you'd first press and hold 'SET'and then press 'TV'. This puts the remote in programming mode, as indicated by the red LED, which should remain illuminated. Now release both keys and punch in one of the listed Philips TV codes. For this project, code 191 works well. The red LED should now go out and the remote is ready for use.

All universal remotes can be programmed in a similar manner, but when in doubt, read the instructions. If the first code listed doesn't work with the control module, then try another.

Once the remote has been programmed, the control module must be set up to recognise the particular equipment address that you've chosen (TV, CD, SAT). Details on how to do this are in the setup and testing section, in Part 2 next month.

Although this project should work with any universal remote, we've tested the following popular models: AIFA Y2E (Altronics A-1013), AIFA RA7 (Altronics A-1009) and BC3000 (Jaycar AR-1710, pictured). For all these models, the setup codes are as follows: TV = 191, CD = 651 (but not for BC3000 remote), SAT1 = 424 and SAT2 = 425.

Note that the 'mute' button doesn't work for all codes and in the case of the AIFA Y2E, is missing anyway! In these cases, you may be able to use the '12' or '20+' buttons instead.



Note that insulating pads should not be used here, as they will impede heat transfer.

Now slip each assembly into place in its PC board holes, taking care not to mix up the different regulator types. **The tabs of the heatsinks should fully engage the holes in the PC board, such that all of the heatsink edge makes contact with the PC board surface.** You may find that the PC board holes are fractionally too small to allow this to happen – if this is the case, use a jeweller's file to remove just enough of the tab to get a neat fit in the holes (see photo).

Finally, push the regulators all the way down the slots in the heatsinks and then tighten up the screws. The regulator leads can now be soldered, taking care that the assemblies remain in place when the board is turned over. Note that you'll find it easier if the devices are mounted in a specific order, as follows: REG2 first, then REG1, REG3 and REG4.

That's all we have space for this month. In Part 2 next month, we will complete the construction and describe the set-up and test procedures.

Train of Thought

TechnoTalk

Mark Nelson

A wandering mind is an erratic thing. All too easily it can roam in any direction, as our correspondent Mark Nelson proves this month. If you are concerned about component obsolescence or interested in see-through components, then read on.

I love reading about electronics, and yes, I confess – I do read electronics magazines from other publishers! The editor of one of these rivals recently named the BC108 transistor as one of the most successful products of all time, along with the 555 timer and its derivatives.

Being a hoarder, I still have stocks of these and other vintage components in my workshop, and maybe you do too. I keep them mainly for repair purposes and would not set out today to build a design using 40-year-old components unless I was feeling more perverse than normal.

No lack of bias

Then I read an article about component obsolescence in another electronics publication and the thought struck me, how easy would it be to build projects from old issues of this magazine? I just happen to have issue 1 of *Practical Electronics* (November 1964) and to demonstrate a lack of bias, also of its younger contemporary, *Elektor* (December 1974). A glance at the designs of 1964 shows up a lot of transistors we don't use today: the 2G102, MAT101, loads of OC71s and a few OC171 devices. I don't think you'd find any of these at a current electronics store. Get back into the time machine.

Moving forward a decade, our Dutch friends were using mainly TUNs and TUPs, transistors that I had forgotten entirely until now. TUN and TUP stood for transistor, universal, *NPN* and transistor, universal, *PNP*. Accompanying them were DUG and DUS, the diode universal germanium and diode universal silicon.

The whole idea was to simplify sourcing of semiconductors by making circuit designs compatible with as many devices as possible, all listed in tables. Effectively, a TUN was a BC107/108/109 equivalent and the TUP was anything that behaved like a BC177/178/179. TTL logic of the 7400 variety took its place now, as well as more exotic ICs such as the 741 op amp and the MM5314 clock display driver.

These were pretty simple times, when you could almost see what each component did in a circuit. Even now, you would not have too much difficulty in sourcing at least 50 per cent of the semiconductors required. Maybe it was the golden era of simple hobby electronics, but that's debatable. What's not in dispute is that soon afterwards discrete components were becoming replaced by integrated circuits of increasing complexity and levels of integration and it's these 'big chips' that are proving very hard to find nowadays.

Component obsolescence

Which brings us conveniently to what the industry calls 'component obsolescence'. This does not refer to the ageing property of some components, although it's a fact that over time some germanium transistors self-destruct through dendritic growth; plastic-cased ICs become unusable through moisture absorption and low-value polystyrene capacitors 'dry out' and go open circuit.

What it actually means is when you order some perfectly straightforward component your supplier says it has been discontinued. 'Rubbish', you think and then discover that not only have Maplin and Rapid dropped it, Farnell and RS no longer list it either. You do a Google search and find not only is the nearest supplier on the other side of the world, but they ship only by DHL and don't deal in less than 100-off.

Someone who knows all about component obsolescence is Phil Innes, chairman of the Electronics Manufacturing Services Association. In a blog on *Components In Electronics* he states the problem is getting worse, thanks to a greater choice of new components and shortening life-cycles. Manufacturers don't want to take chances producing vast quantities of components they may not sell, while distributors cannot afford to warehouse parts that sell only in dribs and drabs.

Volume customers

It gets even trickier when you're dealing with highly function-specific ICs that are only used in niche markets. In cases like this, the semiconductor manufacturers approach their volume customers and ask how many tens of thousands they intend buying over the coming 12 months. They then aggregate these numbers and produce enough to satisfy this demand.

If there's insufficient call for an existing product (which often happens when a superior replacement comes onto the market), they may well kill it altogether. Residual stocks remain in the supply chain for a while, particularly with distributors, but they dry up eventually.

"So what happens when, for whatever reason, you've missed the last time buy deadline?" asks Innes. An obvious solution, he states, is to find a different part with the same form, fit and function (dust off your equivalents book!). Lucky breaks of this kind don't happen that often and then the next step is to look outside the normal channels of supply for the original part that you really wanted. Innes continues, "As a general rule, anything that becomes scarce becomes more expensive and electronic components obey this rule perfectly!"

Penny numbers

So where do you look now? Google is your first call for these obsolete and end-of-life parts, as you may just find a distributor able to supply the numbers you require. If you are looking for more than just penny numbers then it's worth contacting a component broker. Brokers work on a no win, no fee basis, although their commission is not charged separately, but incorporated in the price you pay for the parts.

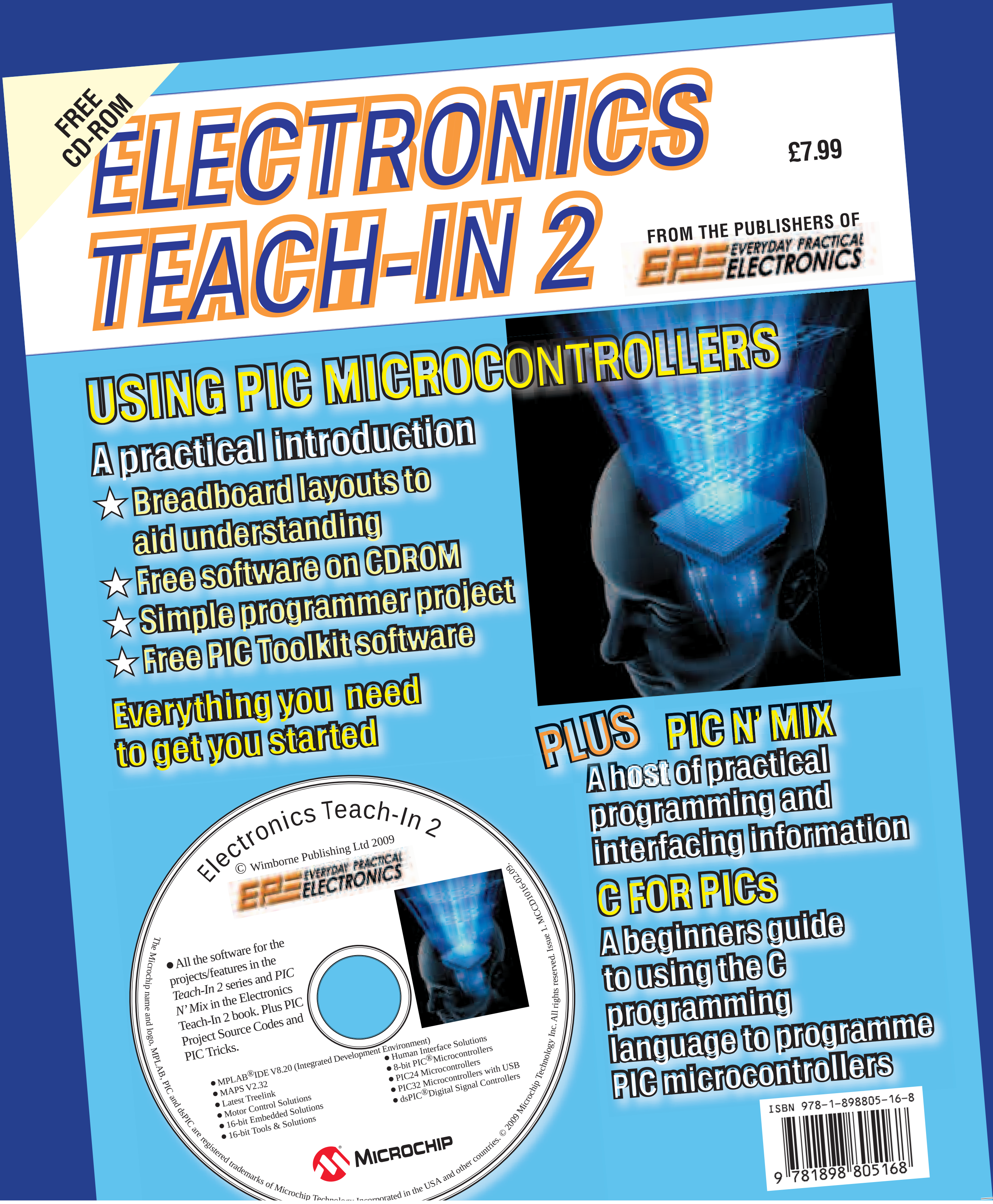
I have dealt with a very effective firm by the name of Ashlea Components of Swindon (**www.ashlea.co.uk**), who have been in this rather specialist business since 1987. They have developed relationships with suppliers worldwide and use their knowledge of the market to source items that you might never find.

But what if your need for, say, obscure unijunction transistors is only a couple? Brokers won't be interested, so instead you approach a dealer. Although few of them advertise, there are a dozen or so dealers in the UK who specialise in impossible-to-find semiconductors and valves. Their names and addresses are too substantial to list here, but you can find all their details at **www.radiocraft.co.uk/directory/valvestubessemiconductorsics.htm**. Incidentally, this list is kept up to date by user feedback, so if you find a dealer's details have changed please contact the webmaster.

Transparent TRRAMs

I suppose valves were the original transparent components, followed by the OC71 when you scraped the black paint off the case to turn it into a phototransistor. But the next big thing is transparent ICs, according to press reports. Researchers in Korea have developed a transparent resistive random access memory chip, which they have dubbed TTRAM.

It is claimed that TTRAM chips are cheap and easy to make, which is why transparent memory chips may appear in all-clear mobile phones and other personal devices within three or four years' time. Alternatively, the technology could stimulate development of clear computer and TV screens, embedded in glass or transparent plastic. Whether this comes to pass is another matter, but there have previously been fashions for crystal clear landline phones and the original Swatch mobile (remember it?) was fashioned in a quite alluring shade of translucent pale blue plastic.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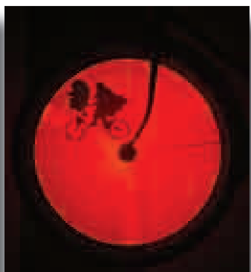
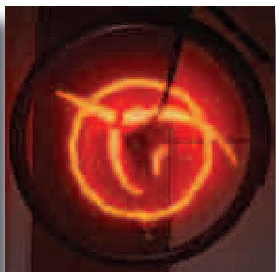
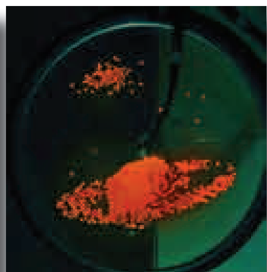
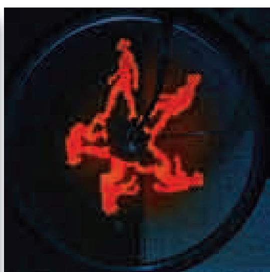
SPECTACULAR

- Support for in-circuit serial programming (ICSP)
- 32 LEDs on each side of each PC board (64 LEDs per board, 192 LEDs total)
- Displays a one-kilobyte image (32 LEDs x 256 radial 'raster lines')
- All LEDs can be driven with 20mA at 100% duty indefinitely. This produces a very bright image.
- Firmware shuts the circuit down automatically when the voltage gets too low, to prevent damage to rechargeable battery packs
- The PC boards fit 26-inch bike wheels or larger.

BIKE WHEEL POV DISPLAY

This project uses POV to produce a spectacular glowing display on a rotating pushbike wheel as you ride along. So what is POV? It stands for 'persistence of vision'. It's a term that's applied to devices that rely on the human eye's tendency to 'see' an image for a short time after it has disappeared.

Designed by Ian Paterson

HOW WOULD YOU LIKE to own the most talked-about pushbike in the school/street/suburb. . . galaxy? Build this POV display and you'll be well on the way.

You really have to see it to believe it – and we've even made it easy for you. As well as the images printed here, there are several more you can view online at www.ianpaterson.org/projects

OK, you've now seen them and you'd have to agree that they look pretty spectacular. You want to do the same for your bike? Just make sure you keep it chained up, because everyone will want it!

Persistence of vision

You probably don't realise it, but you use POV every day – when you watch TV. Movies also take advantage of this phenomenon.

The TV and movie picture is not continuous, – rather (in the case of TV), 25 individual pictures are displayed every second. But your eyes and brain cannot follow the 25 individual frames of picture per second – instead, they 'fill in the gaps' and you 'see' full motion, non-jerky video.

If you slowed down those frames to, say, 10 per second, then you would be able to see the period between each frame and it would become jerky – just like the old-time movies where the hero moves like a Thunderbirds puppet.

Let's take this one step further. Say you had a moving light – we'll make it an LED because they can be turned on and off very quickly – which you flashed on, very briefly, once per second. You'd see this as flashes of light moving along a path. If you changed that to 10 flashes per second, you'd probably still see flashes, but very much closer together. Make that 50 flashes per second and the flashes would all flow into one another. You'd see it as a continuous line of light – even though your brain knows full well that it is flashes you are viewing.

That's *persistence of vision,* and this is the basic theory behind this project. Rows of LEDs are made to flash too quickly for your brain to process, so they appear to be permanently on. The rows of LEDs are mounted on PC boards fixed to a bicycle wheel, so they follow a circular path as the wheel rotates.

By using some clever circuitry to switch the LEDs on and off at particular moments, a pattern or picture can be created – in fact, the display is almost unlimited. It can be anything from geometric shapes to text, cartoon characters and even very high contrast pictures (see examples below).

In a nutshell

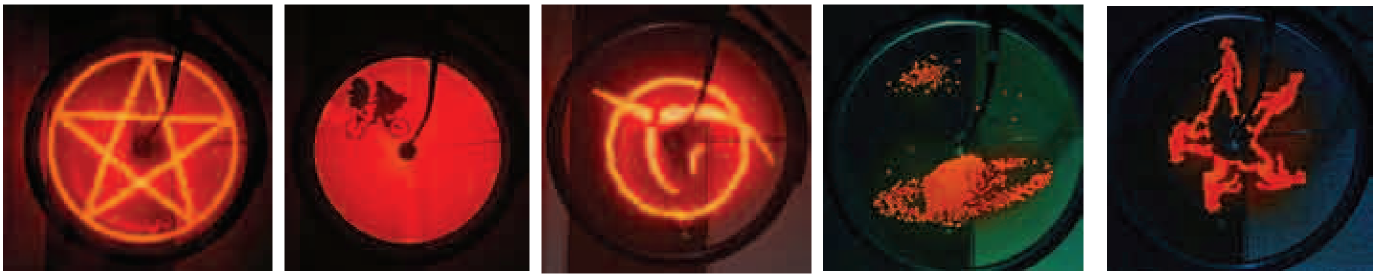
The display consists of three PC boards, each with a row of 32 LEDs on each side (a total of 64 LEDs). These boards are mounted radially in/on the spokes of a pushbike wheel and each has a battery pack mounted near the wheel's hub.

Talk about a WOW! factor: this three-high static display uses different coloured LEDs in each wheel to reveal three different patterns. The 'rider' powers the first wheel and the second and third wheels are driven by friction between the tyres.

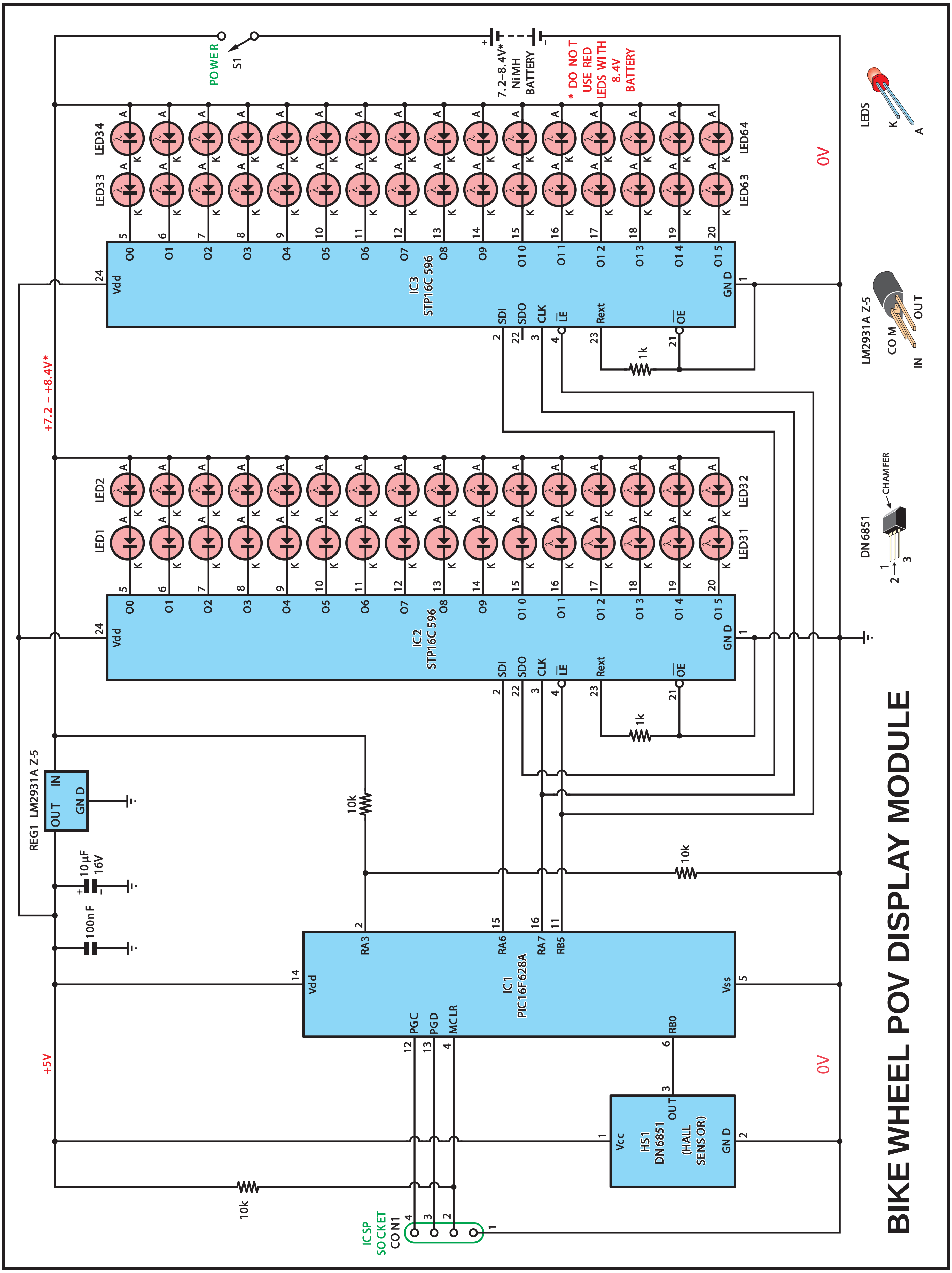
A Hall effect sensor measures the rotational speed of the wheel by sensing a small magnet fixed to the bike frame. This sensor sends speed pulses to a microcontroller, which then turns the individual LEDs on and off in such a way that a static image appears to float inside the wheel.

Circuit description

The complete circuit for one POV display module is shown in Fig.1. Three such modules are required, arranged so that



Here are just a few of the images generated by the author: (from left) pagan star, ET, invisible unicorn, Saturn and evolution!


BIKE WHEEL POV DISPLAY MODULE
IC1 PIC16F628A
IC2 STP16C 596
IC3 STP16C 596
REG1 LM2931A Z-5
HS1 DN6851 (HALL SENSOR)
ICSP SOCKET CON1
POWER S1
7.2–8.4V* NiMH BATTERY
* DO NOT USE RED LEDS WITH 8.4V BATTERY
+7.2 – +8.4V*
+5V
0V
10µF 16V
100nF
10k
1k
LED1
LED2
LED31
LED32
LED33
LED34
LED63
LED64
LEDS
DN6851
CHAMFER
LM2931A Z-5
IN
COM
OUT

each is mounted 120 degrees from the other around the wheel, between the spokes. With the exception of the trigger magnet and battery pack, all components mount on these three PC boards.

The modules, or PC boards, each contain 64 high-brightness LEDs, 32 on each side. An LED on one side is connected in series with an LED on the other, so that the same image is seen on both sides of the bike.

In control

The LEDs are under the control of a PIC16F628A microcontroller (IC1). It is this microcontroller which not only stores the image to be displayed, but also outputs it to two STP16C596 shift registers (IC2 and IC3), which in turn drive the LEDs.

If each LED pair was driven with a dedicated output line, the microcontroller would have to have a very large number of output lines.

Hence, this circuit uses 16-bit constant-current LED sink drivers (IC2 and IC3) which can drive 16 outputs and allow multiple devices to be cascaded together. The STP16C596 also has a separate storage register that allows one set of data to be displayed while the next set is being loaded.

Four lines are used to control the LED outputs: serial data input (SDI), clock (CLK), latch enable ($\overline{\text{LE}}$) and serial data output (SDO).

Each pulse of the clock line causes the data to be 'shifted' over by one place and each pulse of the latch enable line causes the LED outputs to reflect the contents of the shift register.

One kilobyte of image data is stored in the program memory area of the microcontroller and is read by way of a look-up table. The firmware uses four interrupt routines:

- One to provide the time interval between radial raster lines
- One to increment a counter for timing the wheel rotation interval
- One to reset all counters and update the raster interval value every time the Hall effect sensor is triggered
- One that shuts down all LEDs when the battery voltage gets too low.

Fig.1 (left): one POV display module – three are required for the whole project. With 64 LEDs per module it looks daunting, but there are only 12 other components in each!

In fact, after the initial start-up routine, virtually every part of the firmware's execution runs inside an interrupt routine.

Hall effect

We haven't discussed the DN6851 Hall effect sensor yet. Its purpose is to measure the speed of the wheel and supply the appropriate timing pulses to IC1. It's triggered each time it passes a small magnet attached to the bike frame. Its output pulse is sensed by input RB0 on IC1

Timing values for the radial raster line interval are retrieved from a look-up table that exists in the microcontroller's program space. Data for the look-up table is generated with a QBasic program, although you only need to run this program if you want to experiment with different timing values.

When using a 7.2V battery pack, it's better to use a low dropout regulator, such as the National Semiconductor LM2931AZ-5, than the commonly used 78L05. It will continue to provide a solid 5V for the microcontroller even when the battery is at 6V. This is important, because if the supply voltage to the microcontroller drops, so does the internal reference voltage, which would prevent the voltage sensing routine from working properly.

A number of flow charts have been created to illustrate the logic in Spoke POV's various firmware routines, but since our space is limited, these can all be accessed on the website mentioned earlier.

QBasic programs

In addition to the microcontroller firmware, two Qbasic programs are required for setting the timing values and converting image data so that they can be incorporated in the firmware.

POVSLOPE.BAS creates the timebase look-up table. The table produced by this program is linear, so the only parameters one needs to be concerned with are slope and offset. Note that the timing data supplied in the sample firmware is reasonably accurate, so you should only use POVSLOPE.BAS if you plan to experiment with different timing values.

POVIMAGE.BAS is used to convert a raster image into radial data in the form of a series of 'RETLW B'xxxxxxxx';' commands that can be copied and pasted directly into the POV assembly code. The image data is read one pixel at a time as a series of 32 concentric rings. Each group of eight rings ends up occupying one memory page.

Because of the limitations of QBasic, it has been made to read headerless RAW files. The images must be 700×700 pixels, eight bits per pixel, with the pixels being either pure black (0×00) or pure white (0×ff).

Such a file can be created with Photoshop or many other graphics programs. When you've finished creating the image, the final file size should be exactly 490,000 bytes.

To stop the LEDs from lighting up when the bike is stationary, the last raster line is always set to zero (off).

Because the firmware stops incrementing the raster line counter when it reaches the last line in the image, having all LEDs off in that line will cause them to remain that way until the next trigger pulse from the Hall effect sensor.

Software

The software files will be available for download via the *EPE* Library site, access via **www.epemag.com** and also from the author, Ian Paterson – see Firmware panel. Pre-programmed PICs are available from Magenta Electronics – see their advert in this issue for contact details.

Construction

The double-sided printed circuit boards for the Bike Wheel POV Display are available as a set of three (code 711) from the *EPE PCB Service*. The component layout for one board (the other two are identical) is shown in Fig.2, together with top and underside photographs.

After checking the PC board for any copper track defects or solder 'bridges', start construction with the three 10kΩ and two 1kΩ resistors, followed by the 100nF and 10µF capacitors. Of these, only the 10µF radial electrolytic capacitor is polarised. Note, this capacitor is mounted on its side on the PCB, with its leads bent 90° to allow the leads to enter their respective holes in the board – see Fig.2 and photos. Since this is a double-sided PC board, we should mention that, apart from a row of LEDs, the components mount on the side with the writing in the copper.

Next, solder in the three IC sockets (the right way round) and two 'keyed' pin connectors, followed by the polarised regulator (REG1) and Hall effect sensor. One of the trickiest parts of this project is soldering the Hall effect sensors without damaging them.

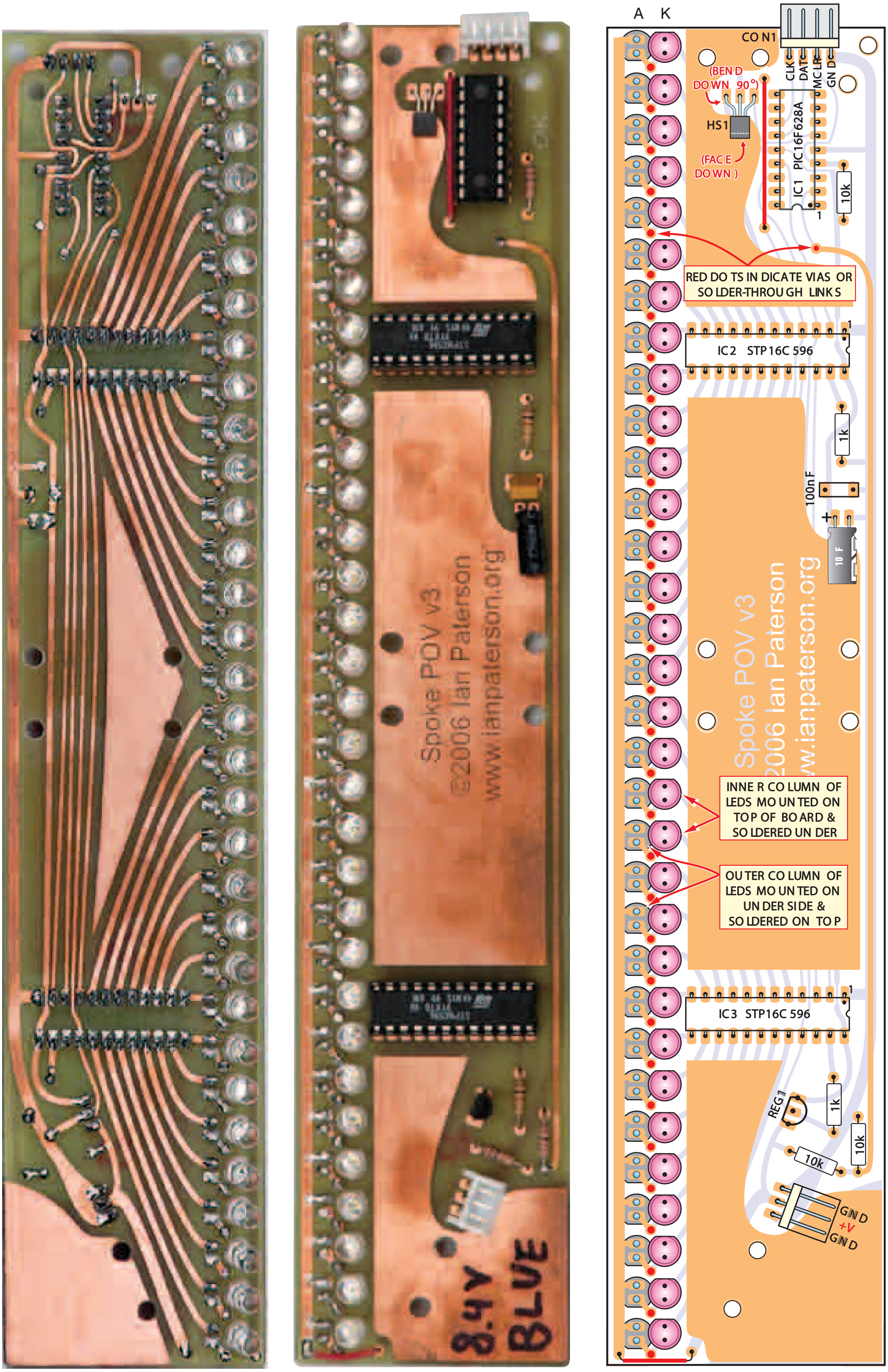


Fig.2: the PC board component overlay (shown from the component side) with matching top and bottom-side photographs of the PC board. The fingerprints are an optional extra! Seriously, the boards should be coated with a PC board (ie, solder-through) lacquer immediately they are made to prevent this from happening – especially as these boards will be out in the weather on the pushbike. In fact, we'd even go so far as to give the whole thing a good spray once finished – making sure you don't get lacquer in the two connectors.

FIRMWARE

Ian Paterson's firmware for this project – 628h.asm, povslope.bas and povimage.bas can be down-loaded from his website at www.ianpaterson.org/projects or from the EPE website, www.epemag.com

Because they are sensitive to both mechanical and thermal stress, you must use great care when attaching them to the circuit board. Their leads must be bent down 90° towards the face which has a chamfered edge on its top. This means that the face will actually be towards the PC board surface when fitted.

When bending the leads, you must hold the sensor lead with needle-nose pliers between the plastic case and the point at which the lead is being bent. This is to prevent mechanical stress at the point where the leads enter the sensor's case.

When soldering, you must also use needle-nose pliers as a heatsink to prevent damage from excessive heat. Once the sensors have been successfully soldered onto the board, there is little risk of further damage.

Soldering the LEDs

You have probably noticed that we have left the LEDs until last. That's because there are a lot of them and they can also be a bit tricky to solder. There are 32 LEDs to be soldered to *each side* of the PC board.

Note first, which lead is the anode and which is the cathode of the LED – there is a flat spot on the body of the LED next to the cathode (labelled 'K' on the circuit diagram). Also, the anode (A) lead is usually longer.

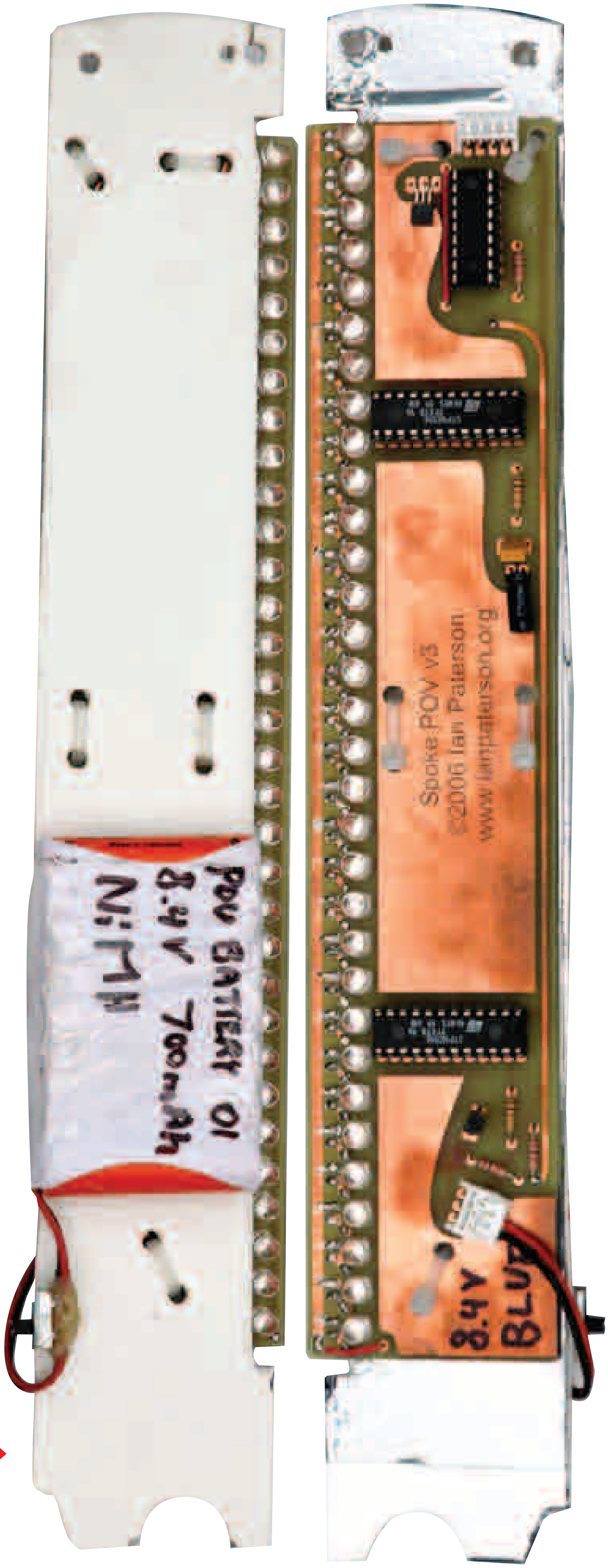
On the top (component side) of the PC board, the LEDs are arranged with their cathodes (K) oriented towards CON1 (the 4-pin connector) while on the bottom side, the reverse is true – see Fig.2.

The LEDs are controlled in pairs, one for each side of the board. This ensures that your chosen POV image can be viewed from both sides of the bike. The LED pairs are connected in series with small jumper wires (red dots on the component layout diagram) through the PC board that serve the same purpose as a PC board 'via' – they connect together the copper tracks on both sides of the PC board where required.

The biggest challenge in soldering these jumpers is that the heat from your soldering iron will travel along the wire and melt the connection on the other side of the board. I found it helpful to use those 'third hand' soldering aids with alligator clips to hold the wire in place.

If you are able to obtain or make PC boards with vias, then these jumpers are not necessary.

Finally, plug the three ICs into their sockets. Be careful to line up the notch in the end of the IC with



Pictured here are the same PC boards shown opposite; this time fixed to their backing 'plate', ready for mounting on the wheel. Note the semi-circle notches at the bottom end to fit into the axle. The top end is rounded to fit against the rim.

Parts List – POV Display *

3 PC boards, each 50 x 245mm, code 711, (available from the *EPE PCB Service* as a set)
3 18-pin IC sockets
6 24-pin IC sockets
3 7.2V or 8.4V 700mAh (or higher) battery packs (do not use 8.4V with red LEDs) – see text
3 4-pin PCB keyed header pin strips (CON1)
3 3-pin PCB keyed header pin strips
3 miniature On/Off slider switches for battery packs
3 magnets – see text
Material for backing plates – see text

Semiconductors
3 PIC16F628A microcontroller programmed with 628h.hex (IC1)
6 STP16C596 LED driver (IC2, IC3) – see alternatives below
3 DN6851 Hall effect sensors (HS1) – see alternatives below
3 LM2931AZ-5 low-dropout regulators (REG1)
192 high brightness LEDs (LEDs 1 to 64)

Capacitors
3 10µF 16V radial electrolytics
3 100nF MKT polyester or monolithic

Resistors (5%, 0.25W carbon film)
9 10kΩ
6 1kΩ

Alternative Parts

STMicroelectronics STP16C596 LED driver alternatives:
Allegro A6276EA
Maxim MAX6969ANG
Maxim MAX6971ANG

Panasonic DN6851 Hall effect sensor alternatives:
Melexis US5881EUA
Allegro A1101LUA-T
Allegro A1103LUA-T

* This list is for all three modules

In daylight, you can see the arrangement of the PC boards and batteries inside the spokes of the wheel. The PC boards, mounted 120° apart around the wheel, fit against the axle and are secured at the rim end via a couple of cable ties onto the spokes. It's important to keep the battery packs (which ever form you use) close to the axle to prevent the wheel getting out of balance.

the notch in the end of the socket. A second check is a small paint dot or indent beside pin 1 – you must make sure this goes where pin 1 is shown on the component overlay.

Loading an image

Since this POV design stores the image in program memory space, the microcontroller must be re-programmed every time you want to load a new image. The process is as follows:

- Create a 700×700 pixel, eight-bits per pixel image and save it with an eight-character filename.
- Edit POVIMAGE.BAS so that it references the new image and run the program. It will save its output with a .ASM extension.
- Copy and paste the .ASM output into the POV firmware file (628h.asm).
- Compile it to produce a .HEX file and program the POV board via the four-pin in-circuit serial programming (ICSP) connector. This connector does not supply power to the board during programming, so you must supply power from a battery pack or an external supply.

Testing

Test the operation of the POV board before fixing it to the spokes. It's a lot easier to fix mistakes on the bench than on the bike! Of course, the microcontroller should be programmed at this stage.

Apply power and wave a magnet in front of the Hall effect sensor. You should see the LEDs illuminate. They won't make much sense (ie, there will be no picture to see) but at least you will know the microcontroller is doing its job.

If they don't light up, turn the magnet over and try again. The faster you wave the magnet in front of the sensor, the faster the LEDs should flash. If this test fails to illuminate the LEDs, the most likely causes are a defective Hall effect sensor or a bad program.

Batteries

The battery voltage needs to be high enough to allow the regulator to provide 5V for the microcontroller and also just high enough to allow the LED drivers to deliver up to 20mA through each LED pair. Try using a 7.2V battery pack for LEDs with a low forward voltage (such as red) and 8.4V for other colours (such as white and blue). Be sure not to use a battery voltage that's more than about 2V higher than twice the forward LED voltage, otherwise the LED drivers may be damaged.

In the prototype, battery packs were made up from AA NiMH cells. I used 700mAh cells, but with 2500mAh now available, 1000mAh and even 1500mAh are becoming quite cheap. The larger the capacity, the longer your display will last.

You can use six cells (for 7.2V) or, as long as you don't use red LEDs, seven cells (8.4V) in your battery packs – it's more a case of getting a suitable holder. All three packs should be the same weight to avoid unbalancing the wheel.

An alternative, albeit a bit heavier, is to buy 7.2V or 8.4V battery packs intended for radio controlled models. High power (3500mAh+) ones are expensive, but you can often find lower capacity types on eBay for less than £10. Just make sure you mount them so they can't fly off!

Wheel mounting

The accompanying photo shows the position of the PC boards on the bike wheel. It's important to note that the inner edge of the PC board sits right up on the axle and that the whole thing is centred between the spokes, so that the board is right in the centre of the wheel.

To mount the PC boards in the wheel, a protective backing was made out of 3mm sintra (often used as a rigid backing onto which printed material can be mounted), one side was covered with anti-static plastic (cut from a motherboard bag), and was attached to the solder side of the PC boards using plastic cable ties.

We are not sure if the anti-static plastic is of any real benefit, but it was used as a precaution in case a static charge builds up on the sintra as the wheel spins.

At one end of the sintra, a crescent-shaped notch was cut to match the radius of the wheel front hub shaft. On the other end, a notch for the spoke nipple was also cut.

All that is needed to secure a PC board to the wheel is two cable ties at the spoke nipple end – the other end stays put because the crescent-shaped notch engages around the wheel hub.

To keep the hub end of the boards in place, two short sections of plastic hose were used. These were slit down one side, wrapped around the hub shaft and attached with cable ties. These act as spacers that prevent the boards from sliding laterally along the length of the hub shaft.

Note: these boards will fit a 26-inch or larger wheel. Also, when using three boards, it's easier to mount them in a wheel with a number of spokes that's divisible by three (eg, 36 spokes).

Mounting the magnet

To trigger the Hall effect sensors, the author used a stack of four magnets from an old 3.5-inch hard drive.

The stack of magnets were placed on the inside of one of the bike forks, immediately above the region under which the Hall effect sensor passed, then secured in place with a strip of tape.

Other suitable magnets would be one or more of the rare-earth or so-called 'super magnets' which are enormously powerful for their size. ***EPE***

More information?

There are plenty more notes, flowcharts, firmware and graphics on the author's website, just set you browser to:
www.ianpaterson.org/projects

Solar Water Heating System Controller

Part 1

By EDWARD CHASE MA(Cantab) CEng MIMechE

Save on energy bills with no CO2 solar energy

EPE has not published a controller for solar hot water systems since an op amp based differential one in Feb 1977 *Practical Electronics*. Nowadays, most controllers are microprocessor based with LCD screens and physically resemble modern central heating programmers. The design here does not attempt to copy these but instead takes a different approach. The author deliberately did not look at commercial designs while doing the initial design, intending that he would come up with some novel ideas rather than generating a 'me too' design.

So this controller provides some functions that you will not find on a commercial controller, **needs no mains supply,** produces no CO2 output in use and is cheaper to build than buying one of similar complexity off the shelf. It does, however, implement many functions found in commercial controllers.

It was designed to work with the author's Solartwin solar system, but will operate with almost any solar water system, including swimming pool heating. Some minor software and component changes may be needed with some suppliers' systems, but enough information is contained in this article for readers to make these modifications. It could be used to make an existing solar system of almost any type more efficient.

The component cost for the controller is around £50 plus box and PCBs for the full version. A £35 version is possible too, but with fewer features. You may well have many of these components already and most are not critical. Commercial controllers could cost £80 to £300 with the cheaper ones not having many features.

Solar hot water systems have always had a reasonable payback time, compared with say double glazing, as long as you don't spend too much on the system. With inevitable long term fuel price rises, now a very good time to install a system, particularly if you have to use oil, electricity or other expensive fuel sources.

Solar panels

Solar hot water systems are 50% to 60% efficient at converting solar energy to something useful, compared with only 10% to 15% for electric photovoltaic (PV) panels. They are also less expensive per square metre. Much more energy is collected per £ of system from a hot water panel than from an electric one. Thus, while there is a lot of publicity at the moment about PV systems and, being all electric, they may appeal more to *EPE* readers, the payback time of PV systems remains far longer than hot water systems, indeed arguably PV never pays its cost back.

Solar collectors for hot water are usually either:

- Evacuated tube
- Flat metal panel in a glazed fronted insulated box
- Focused mirrors that track the sun.

The first two are common in domestic situations. The author has installed three systems using a Solartwin flat plate panel.

For swimming pool heaters the water temperature in the panels is less, thus moulded plastic collectors, not in a glazed fronted box are common, as they are less expensive.

The panels feed hot water to one of:

- Extra heat exchanger coils in the Hot Water Cylinder (HWC) – in direct system
- Direct feed into existing cylinder (direct system)
- Added preheating cylinder that in turn feeds the main HWC

There are a number of problems that need to be overcome to have a successful system, such as:

Freezing

In all of the UK and many other places there is a danger of freezing, which may burst the pipes, pump or panel. The last thing you want is water pouring through your ceiling from a leak. Most modern systems get around this by using a closed loop through the panel, pump and HWC which is filled with antifreeze – like in a car radiator. This fluid never mixes with the water to the taps.

Alternatives are draining the system in winter, having a system that self-drains when the pump is not pumping or having a system which uses largely plastic or silicone piping. This is freeze tolerant because it can expand a little to accommodate any ice.

The Solartwin system uses the latter approach; all piping is silicone rubber and the pump is a special one that can tolerate being full of ice. This has the important added benefit that laying the pipe is a whole lot easier than soldering up long runs of copper pipe.

Electrical power

The power to the controller and pump can be significant, up to 17% of the total energy input. So it takes 17% longer to pay back the capital cost of the system and CO2 is emitted.

This waste is not helped by most systems using standard mains voltage central heating type pumps, which are inefficient.

Legionella

All hot water systems are subject to growth of *Legionella* bacteria, even though it is rare to hear about a case in domestic houses due to the small size of the system. Solar systems are slightly more susceptible, as the water can be just lukewarm if it has not been very sunny.

Official advice is to avoid water temperatures between 20°C and 45°C, therefore it is important to heat the water to well above this (60°C to 65°C is recommended by some) regularly with back-up heating to kill off any bacteria. This is particularly important in winter, as the panel may rarely have fresh water pumped through it so Legionella may grow there.

This controller helps to solve all the above problems, although the freezing is not solved by the current software version, even though the hardware is suitable. It can't do much about the following, which are inherent to the type of system you choose.

Handling excess heat

There may be times when the HWC is adequately full of hot water and the panel is still collecting heat or the pump/electricity supply has failed. The excess panel heat has to be safely dumped. This can be done by boiling off the water and allowing the panel to radiate when it's empty of water. It will become exceedingly hot, so needs special construction to prevent damage.

Alternatively, a special coating on the panel can be used that radiates much of the incoming heat when the panel temperature is above say 80°C. The Solartwin system uses this approach.

Hot water cylinder

Most systems use a closed loop antifreeze circuit, therefore the HWC has to be changed for a new one with an extra heat exchanger coil in it. Thus, it has one coil for the solar panel and one for the central heating boiler. It is useful to increase the cylinder size while doing this, as is helps to collect more heat on sunny days to make up for non-sunny days. But this new tank adds £100s to the system cost.

On the Solartwin system, known as a Direct System, it uses the existing HWC as long as it's larger than 100 litres, which most are. It feeds the hot water from the panel straight into the top of the HWC, so no extra coils are needed. It has the added benefit that this panel-derived hot water is kept at the top of the HWC where it's needed, rather than being diluted by colder water lower down.

Types of controller

Several different types of controller are available:

- **Simple differential**. Measures panel and HWC temperatures and the pump is turned on when the panel temperature exceeds that of the HWC. Has a few LED indicators. This is like the earlier *Practical Electronics* design.
- **Microcontroller**. Does the same as above, but uses a microcontroller and has an LCD screen to indicate what is happening in the system and to alarm any fault conditions, such as faulty sensors or an overheating panel.
- **PV**. It use a small PV panel of about 5W to power the pump and if the sun shines the pump runs. The pump speed is proportional to the level of sunshine so mirrors the heat into the panel, therefore no electronics is needed for pump control.

The pump is a high efficiency, low voltage, low power DC unit. No mains electricity is needed, so it negates the 17% loss mentioned earlier, but with a little increased capital cost for the PV panel and special pump, offset by no controller being needed.

The original Solartwin design (without a controller – it now has one) used the PV approach. While very simple and efficient it does have some downsides, such as:

- The water temperature lags sunshine levels by tens of minutes due to the thermal inertia of the panel, so the pump turns on and off too early
- Tracking of pump speed and panel temperature is not completely accurate, even at a steady state
- No display of water temperatures unless thermometers are added
- No fault monitoring.

The controller presented here gets around these 'downside' problems

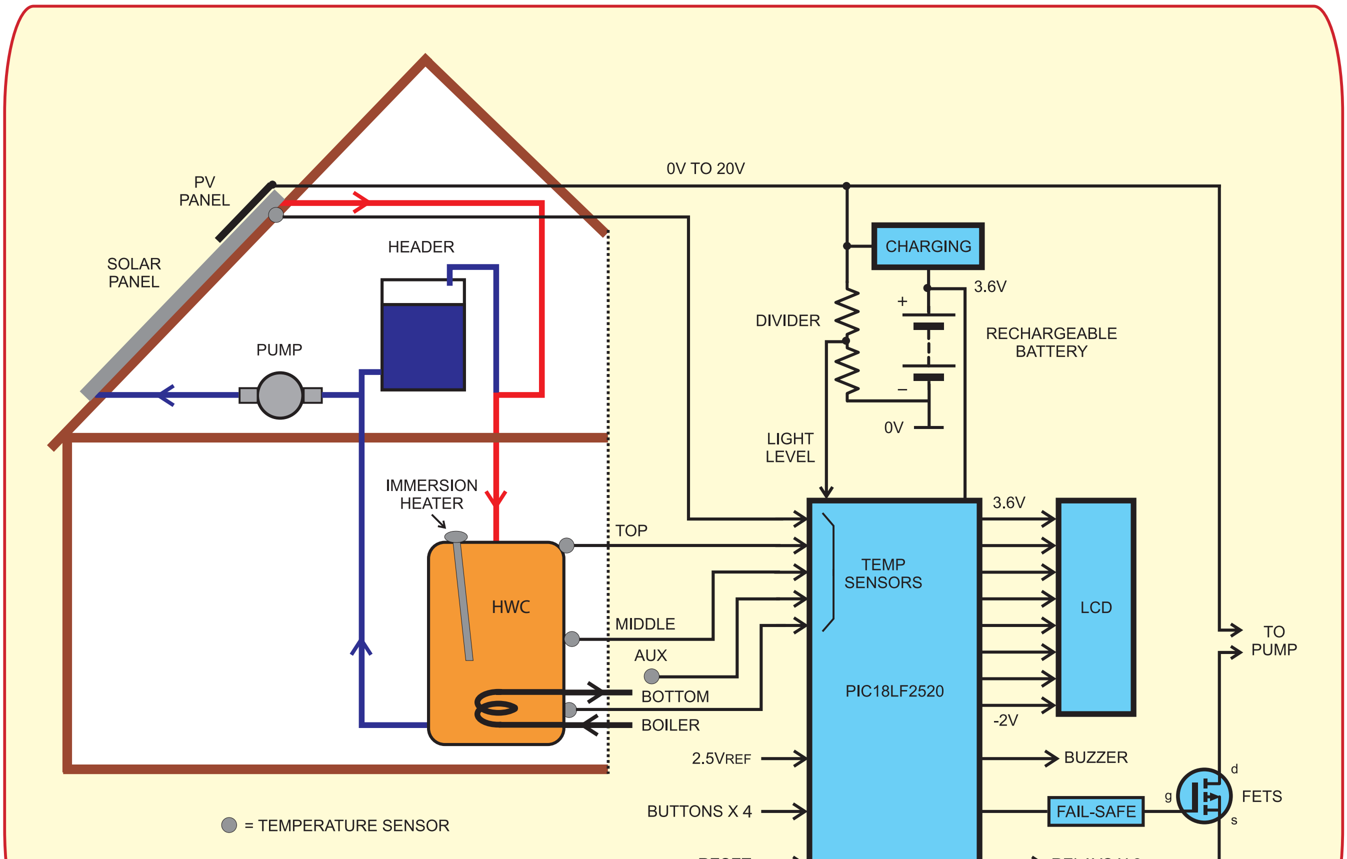


Fig.1. Block diagram of the Solar Water Heating Controller

and adds some further functionality, such as controlling the backup heating (usually a gas boiler in UK), logging the kWh extracted from the panel and controlling an auxiliary output, such as for greenhouse heating or a motorised sun awning.

The latest Solartwin systems do include a controller, but do not have all the features of this controller. This one could be used as well as, or instead of, a Solartwin controller. It could be used to make an existing non-Solartwin solar system of almost any design more efficient.

DIY system

It is quite possible to make a solar heating system for a few hundred pounds using second-hand parts, such as an old radiator painted black placed in a glass fronted box. YouTube has some videos on how to do this. A second-hand central heating pump, a simple controller and an additional coil placed in the HWC through the immersion heater boss completes the system. This was an approach often taken in the early days of solar heating.

However, such systems, while they may work and have a short payback time, will be rather unreliable and not very efficient. Custom built solar components are better if you can possibly afford them and there is much choice now.

The Solartwin system, or other direct system, is probably the easiest system for DIY installation as its silicone pipes are much easier to install than copper ones, it has no mains electricity to connect and does not need to be filled with antifreeze. It's available direct from the maker as a DIY kit for £2,543. The *£100 off* offer to *EPE* readers (see parts list) means that you can recover the cost of the Solartwin controller if you build this design. The internet will turn up various all-DIY systems if you have the plumbing and carpentry skills to make them.

If you have an existing system using a mains-driven pump, then you can use this controller with the pump, or better still, replace the pump for a low voltage DC one, perhaps with a peak power point tracker to cut the 17% waste.

Design outline

A block diagram of the system is shown in Fig.1. The PV panel charges a battery to keep the controller running when there is no light. It also powers the pump in the normal method used by PV powered systems. However, FETs control the pump too, so it is only on if the PIC -based controller requests it to be on and there is enough sun to power it.

The PIC accepts inputs from up to five temperature sensors and also reads the sunshine level from the PV panel. From these, it calculates whether the pump needs to be turned on. The pump drives the water from the HWC around the panel and back to the top of the HWC.

The controller also drives a relay for switching on the backup heating to top up the water temperature, if sunshine is inadequate, and also an optional auxiliary relay that responds to the optional fifth (AUX) sensor. This fifth sensor and relay act like any normal temperature controller and can be used for whatever use you want, independent of the solar

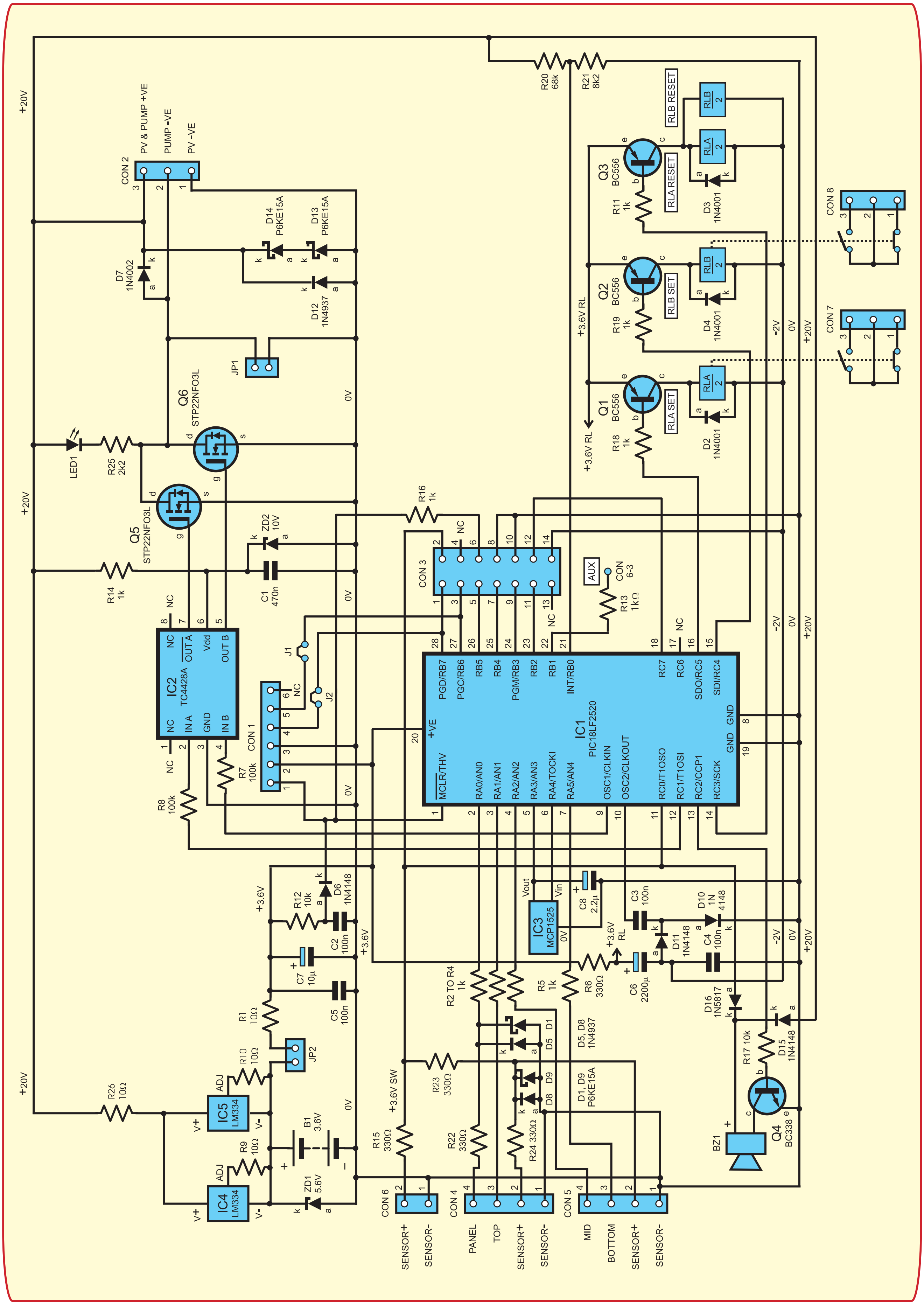


Fig.2. Main circuit diagram of the Solar Water Heating Controller. Points J1 to J3 are just PCB links (see Part 2)

controller functions; for example as aquarium or space heating, a sun awning, greenhouse/conservatory vents/heating, giving a greenhouse frost warning.

A buzzer warns of a dangerously hot solar panel or under/over temperature on the auxiliary sensor.

The PIC drives a 16 character by two line LCD to display items such as temperatures, pump status, sensor faults or kW input. Four menu buttons and a reset are provided.

Modes of operation

The controller has two modes of operation. In differential mode it compares the panel temperature with the lowest sensor on the HWC. When the panel exceeds the HWC by 3°C (settable in software) the pump turns on and off again, with a software settable hysteresis.

Although very energy efficient, this differential mode has drawbacks. For example, in a direct system design, in the morning when the sunshine is at a low level the pump adds lukewarm water to the top of the HWC, although it mostly falls to lower down the tank. So water drawn off in the taps could be lukewarm if you have not recently used backup heating. So, an alternative absolute mode can be set by software. In this, the pump will not turn on in the morning until a set panel temperature is reached, say 60°C. This is enough to kill Legionella in the panel and keep the top of the HWC hot. Three hours before dusk though, in order to extract maximum heat out of the panel before dusk, and in the hope that the tank will have been well heated up by then, the system reverts to differential mode.

Detailed circuit description

The core PIC, LCD and menu buttons (see Fig.2 and Fig.3) are standard designs, as used on many recent *EPE* projects, so we will not dwell in detail on how these items work.

The PIC used is an 18LF2520 instead of the older and better known 876/877 range as it is has more memory, lower power, an internal oscillator and more A/D inputs. The PIC's internal precision 8MHz oscillator divided down to 250kHz is used, so there is no external crystal.

The PIC uses five A/D inputs to measure the voltage on MCP9700A temperature sensors, which output 10mV per degree C, plus an offset of 0.5V, so –20°C is 0.3V and 100°C is 1.5V. The MCP9700A is more accurate than the PT1000 thermistors commonly used in these applications and is much less expensive, at around 40 pence, compared with around £10 for PT1000s.

A set of four or five PT1000 sensors would double the component cost of this project, although it's possible to use one PT100 on the panel, and the MCP9700A elsewhere if the software were changed. A MCP9700A can run stably with long leads.

The photovoltaic panel that powers the whole system mounted above the solar panel

Four pushbuttons on the LCD PCB are connected to Port B of IC1, to enable menus to be driven, A reset button operates on $\overline{\text{MCLR}}$ pin 1. This button and R16 are optional because removing JP2 has the same effect. A reset button is only really useful for software development.

Outputs from the PIC drive the LCD in a conventional manner from Port B (shared as inputs from the pushbuttons

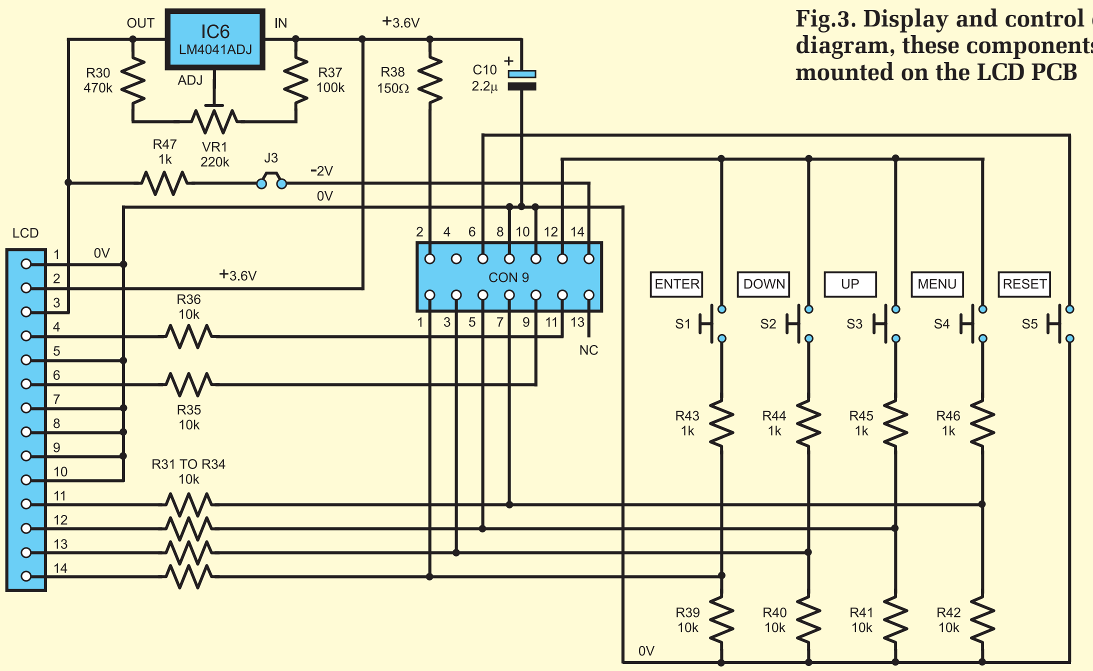


Fig.3. Display and control circuit diagram, these components are mounted on the LCD PCB

Parts List – Solar Water Heating Controller (Main PCB)

1 PC board, code 712 (Main), size 127mm × 74mm (available from the *EPE PCB Service* next month)
1 ABS instrument case, size 150×80×50mm
2 5V dual coil latching relay (Omron G6CK-2114P-US 5DC) or 2117P – (RLA*, RLB*)
1 3.6V 150mAH NiMH battery PCB mounting (B1 – see text)
1 2-20V buzzer (BZ1*)
2 2-pin header with jumper 0.1in pitch, (JP1, JP2)
1 6-pin SIL header, 0.1in pitch (CON1*)
1 14-pin IDC socket, dual row (CON3)
1 14-way ribbon cable 0.05in pitch, 11cm long
2 4-way, 0.2in screw terminal strip (CON4, CON5)
4 3-way 0.2in screw terminal strip (CON2, CON6* to CON8*)
1 28-pin turned pin IC socket 0.3in pitch
1 8-pin DIL IC socket*
1 2-core screened cable – length as required
1 2-core screened high temperature cable – length as required
M3 screws, nuts, pillars, washers as required for PCB mounting

Semiconductors
1 PIC18LF2520 microcontroller programmed with the Solar Water Heating System Controller software (IC1)
1 TC4428A FET driver (IC2)
1 MCP1525 2.5V reference (IC3)
2 LM334 current regulator (IC4, IC5)
5 MCP9700A-E/TO temperature sensor (ICsens 1 to 5)
3 BC556 PNP transistor (Q1* to Q3*)
1 BC338 NPN transistor (Q4*)
2 STP22NF03L FET (Q5, Q6)
1 5.6V 500mW Zener diode (ZD1)
1 10V 500mW Zener diode (ZD2)
4 P6KE15A suppressor diode (D1*, D9*, D13*, D14* (** on 6V system)
4 IN4001 diode (D2* to D4*, D7)
3 IN4937 fast recovery diode (D5*, D8*, D12*)
4 IN4148 diode (D6**, D10, D11, D15*)
1 IN5817 Schottky diode (D16**)
1 Red LED (LED1*)

Capacitors
1 0.47µF 16V ceramic/poly (C1)
1 0.1µF 6.3V ceramic/poly (C2 to C5)
1 2200µF 10V electrolytic (C6*)
1 10µF 6.3V electrolytic (C7)
1 2.2µF 6.3V electrolytic (C8)
5 1µF ceramic SMD 1205 or 0.1µF leaded, see next month (C sens 1 to 5)

Resistors (0.25W, 2% metal film, except R1 (0.125W))
4 10Ω (R1, R9, R10, R26**)
5 1kΩ (R2 to R5, R13*)
5 330Ω (R6*, R15*, R22**,R23, R24**)
2 100kΩ (R7, R8)
5 1kΩ (R11*, R14, R16*, R18*, R19*)
2 10kΩ (R12, R17*)
1 68kΩ (R20) or 30kΩ for 6V PV panel – see text
1 8.2kΩ (R21)
1 2.2kΩ (R25*)

Items marked * and ** – see text

(Display PCB)

1 PC board, code 713 (Display), size 110mm × 65mm (available from the *EPE PCB Service* next month)
1 14-pin IDC header, dual row right angle (CON9*)
1 DEM16216SGH 16 character by 2 line 3V LCD display module – Maplin N25AZ (LCD – see text)
1 LM4041ADJ adjustable reference (IC6)
5 Tactile switches, 12mm with buttons (S1 to S5*)
M2.5 and M3 screws, nuts, pillars, washers as required for PCB and LCD mounting

Potentiometer
1 220kΩ subminiature trimmer, horizontal (VR1)

Capacitor
1 2.2µF 6.3V electrolytic (C10)

Resistors (0.25W, 2% metal film)
1 470kΩ (R30)
9 10kΩ (R31 to R36, R39 to R42))
1 150Ω (R38)
5 1kΩ (R43 to R47)
1 100kΩ (R37)

SPECIAL OFFER

Solartwin has offered* EPE *readers £100 off the price of their complete system if readers order direct from them and send a photocopy of the front cover of this issue with the order before 1 Sept 2009. Note that Solartwin do not sell individual parts for their systems, and do not warranty their system if fitted with a different controller. (See their advert on page 45 for contact details).

which are activated when PIC output RC7 is high.)

Power supply

The more novel parts of the design are in the power supply arrangements and the outputs. All power is derived from a 5W PV panel of 20V open circuit, which falls to about 15V when the pump is running with full sun. It's a notional 12V panel, usually used for 12V battery charging; note that 20V is much more than its notional specification and so the controller's design allows for this wide variation in supply voltage.

There is an option to change the voltage to a notional 6V panel, as the latest Solartwin system is supplied with this. Simply change the voltage in the software's menu and in this article for 6V and, for the pump supply side, halve the voltages referred to and double the currents. Change R20 to 30kΩ to make the voltage at the PIC the same as if it were a 12V panel. Similarly, a 24V or 36V panel could be used, although there is no software option for them and check the components on the PV supply side are able to withstand the voltage and power dissipation at these higher voltages, see LED1, IC2, IC4 and IC5.

The PV supplies five parts of the circuit:

1) It charges the backup battery (B1) via IC4, a constant current regulator set by R9 (10Ω) to 9mA (*must not exceed 10mA*). IC5 and R10 add another 9mA,

so after the main circuit has taken about 5mA it leaves 13mA for the battery. IC4 and IC5 will keep the current constant if there is more than 1V across them. Down to 0.5V they still conduct, but the current is less. For an 80mAh battery R9 and R10 should be 13Ω.

IC4 and IC5 also act like diodes, preventing the battery back feeding the circuit around IC2 and the PV panel when light levels are low, although most PVs have blocking diodes in them to prevent this. Zener diode ZD1 clamps the battery voltage to a value that will not damage the PIC if the battery becomes open circuit or otherwise faulty. Jumper JP2 enables the circuit to be isolated from the battery when being worked on or when the PIC is programmed. Resistor R1 must be 0.125W maximum as it limits current in the event of shorts and eventually goes open circuit like a fuse.

The battery can be 3.6V NiMH or 3.7V LiPoly, but *not NiCad,* as the memory effect will lessen its effectiveness. An old mobile phone battery in reasonable condition may suffice. Higher capacity cells will last longer as, at the specified 150mAh, in winter every night there will be quite a significant discharge of the cells and they only last 500 or so compete cycles.

If using Li (lithium), follow the maker's instructions carefully and reduce ZD1 voltage to 4.2V (eg a 3.6V and a 1N4148 in series), or whatever value is relevant to that battery, so it is not overcharged.

2) It feeds PIC pin 21 (RB0) via an approx 10:1 voltage divider (R20 and R21) so its voltage can be measured to estimate the sun's brightness and hence heat input into the panel.

3) It feeds the positive side of the pump just like the normal Solartwin design with the earthy side of the pump switched by the output FETs, whose supply also comes from the PV.

4) It feeds IC2, which provides enough output drive voltage to power the FET gates. ZD2 limits the supply voltage to 10V to prevent damage to IC2 and reduces IC2's supply current.

5) Diodes D15 and D16 ensure that the buzzer is fed from the higher of the PV voltage or the battery. The buzzer must work down to about 2V due to the voltage drop across the PIC, D16 and Q4, so D16 is a Schottky type to minimise drop. The volume will be loud for a panel overheat, but soft for other warnings if the PV voltage is low. If just used as a panel overheat warning, then you could connect it straight to panel positive and eliminate D15 and D16.

Power rails

The following power supply rails are provided:

1) PV for use as mentioned above, reduced to 10V for IC2.

2) 3.6V SW (switched by PIC pin 11 [RC0] for power saving) for buzzer, temperature sensors and LCD.

3) 3.6V straight off the battery for most of the circuit.

4) 3.6V RL (relay) a higher current supply for the relay coils.

5) –2V for LCD and relays

None of these supplies are voltage stabilised apart from the 10V one, so they will vary with battery and PV voltage. Thus a 2.5V voltage reference (IC3) is used to ensure that the PIC measured voltages are referenced to a stable value. This can be switched off by PIC line RA4 (pin 6) for power saving, but this is not done with this version of the software as it is a low power reference already.

PIC pin 10 is a clock out line running at 62kHz derived from the internal PIC clock. A voltage doubler/inverter consisting of D10, D11, C3 and C4 uses this clock to turn the 3.6V supply into a –2V rail. Paired with the 3.6V rail this –2V gives a total nominal 5.6V difference between these rails. This is used by the LCD contrast bias and the relays as a substitute for the conventional 5V supply that they need.

Latching relays

A normal relay's coil current is many times the total current consumption of the whole controller. So the heating and auxiliary outputs use latching relays for power saving, as only a 5ms pulse is needed to change their state.

The coils are fed off the 5.6V supply via the driving transistors Q1 to Q3, which ensure the coils receive about 5V despite the voltage drop in the transistors. The two reset coils are paralleled so both relays turn off together. The software turns one on again immediately should it be necessary. All this is done so fast that only a couple of mains cycles should be lost, meaning the load will hardly notice the break in supply.

As the relay coils briefly consume much more current than any other component, special arrangements are needed to drive them. The –2V supply cannot provide the current needed, so the large value capacitor C6 is charged via resistor R6, which limits the current to what the –2V rail can deliver. C6 provides enough current to deliver several pulses in rapid succession to the coils before its voltage drops too far. It is charged up again in less than one second.

Lightning

As a lightning strike on or near the solar panel will feed a large spike down the PV and panel temperature sensors cables, a form of lightning suppression is added, consisting of transient suppressors D1, D9, D13 and D14 and fast recovery diodes D5, D8 and D12. Current limiting is provided by resistors R22 and R24. These diodes also protect the controller against reverse connection of the PV.

These diodes and R22 can be deleted if your installation does not have a lightning risk, (the author's is low down on a greenhouse roof and so unlikely to be struck with lightning as it would hit the top of the two storey roof instead). Replace R22 with a link if not fitted.

It is not claimed that this circuit will protect against very close strikes, but some protection is better than none for near misses. Ideally, spark gaps would be added too, but these are expensive.

Low current design

Everything, apart from the pump driver, runs at low current/voltage/clock speed (250kHz) to keep running current from the battery low. It drops from 5mA to 2.5mA when the battery is not charged, as the lower battery voltage lowers dissipation. Thus, it runs off the PV panel even in winter when light levels over a day are low and PV voltage may not rise above 5V to 10V very often. A by-product of the low current design is that, despite many shorts and mis-wirings during development, no component was damaged as, even under fault conditions, the currents are usually too low to hurt anything.

Resistors R7, R8, R31 to R36 are high value to prevent the PIC from supplying significant current to IC2 and the LCD via its data lines in the event that these have their supplies off for power saving. The prototype used no resistors here and sufficient current was fed from the PIC to flash up random characters on the LCD. Resistors R2 to R5, R13, R15, R21, R22 and R24 prevent the PIC or reference being overloaded if there is a sensor wiring short, or the PIC supply rail falls below the A/D input voltages.

LCD

The LCD must be able to work off a 3.6V supply on its logic side. The one specified is OK; many types only quote down to 4.5V, but in practice may work with less as the logic chip is usually a 2.7V device. The LCD contrast though must be driven by a stable supply 4.5V to 5V below the 3.6V rail. IC6 stabilises this supply and VR1 sets an appropriate voltage for good contrast.

IC6 must have low quiescent current and produce some output even when there is less than 5V across it, therefore a voltage reference is used rather than a regulator. The PIC carries on running until its supply rail gets down to 2V, so even if the LCD is unreadable due to insufficient voltage, the PIC is still running, thus time and kWh values are not lost.

The LCD and IC6 are the largest power consumers, so they are turned off between midnight and dawn unless any button is pressed to reactivate them for a few minutes and briefly every hour for checking the sensor inputs.

PIC output pins 9 (RA7) and 12 (RC1) drive IC2, a TC4428A dedicated FET driver driving two medium power FETs (Q5, Q6). These have a fairly low on resistance of 0.08Ω, but are paralleled here to make it even lower.

Since the Solartwin 15V pump consumes much less than one amp heatsinks are not needed, indeed in the prototype the FETs were not even installed as an MCP1405 was used for IC2, capable in itself of delivering 0.5A continuously. Beware that many pin compatible devices to the TC4428A are available, but may consume more current, especially if they are without the 'A' suffix.

IC2, unlike normal discrete FETs, can work with the 2V to 4V logic drive from the PIC. It outputs sufficient voltage and current to drive almost any *n*-type FETs. So Q5 and Q6 can be very high current and voltage ones if mounted off board, as the PCB tracks cannot take more than about 5A or voltages higher than about 50V. LED1 indicates that the pump is on and can be mounted on the front panel if required.

Fail safe features

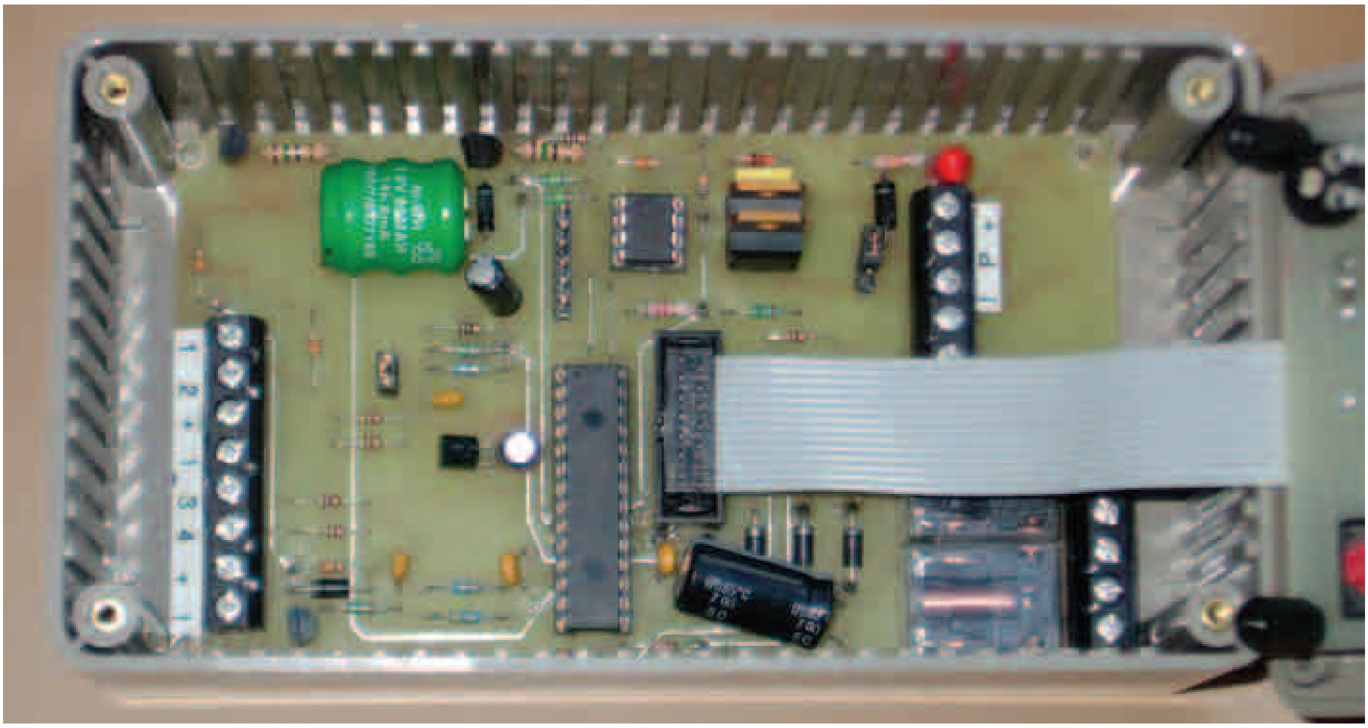
The use here of IC2, driven separately from the PIC's supply, provides the potential for a measure of protection against circuit and software failure. The author (a Safety and Reliability Engineer by profession), thought it would be useful to incorporate some fail safe features, which only add about £1 to the component cost.

The circuit is thus arranged so that, under most fault conditions, it defaults to normal non-controller operation, with the pump permanently connected to the PV. This is safer and more energy efficient than the pump not running.

This fail safe operation works as follows. IC2 contains an inverting and a non-inverting driver and the two inputs are driven opposite to each other by two different ports on the PIC. Thus, every time the PIC outputs a high on one it also outputs a low on the other. Therefore, if the PIC or 3.6V supply fails, the battery goes flat, or the software crashes, both IC2 inputs normally go low, so the inverting FET switches on the pump. If there is a fault causing both to go high the same happens, but using the non-inverting FET.

In this way, it is fairly certain that one or other FET will be on if there is a circuit failure or under some software errors, thus the pump runs under PV voltage. The one operating FET will dissipate more power, so make sure the pump current can be taken by just one FET. The specified ones are good for tens of amps, especially with a heatsink.

If both FETs fail or there is a PV, IC2, motor or wiring fault, then the pump will stop but the controller should still be running under its battery power and will indicate high panel temperatures, warning the user that there is a fault, at



The main PCB – note the lighting protection diodes and buzzer are not fitted. This board will be described next month

least until the battery goes flat. The optional buzzer helps here because it alerts the user to an overheating panel faster than just relying on the user to notice that the LCD is indicating an overheat.

Under controller fault conditions, a jumper inserted on JP1 will keep the pump running under PV power until repairs can be made.

Multiple failures

The main faults that are not protected against are multiple failures due to say a lightning strike, some software errors or a major sensor inaccuracy, perhaps due to cable corrosion.

A direct lightning strike would kill almost any type of controller. At least with this one you can easily test and replace the components to fix it, whereas a commercial one with unknown circuit and software, and using surface mount components would be classed as a throw away, costing over £100 to replace. Judging by the piles of dead controllers the author once saw in a solar shop, failure is not uncommon in commercial controllers.

The MCP9700A temperature sensor is accurate to ±2°C up to 125°C. Only panels under fault conditions reach these temperatures. Above 125°C and below 150°C reliability will be degraded, but the sensor should last well as these high excursions should be very rare.

An evacuated tube system under fault condition may exceed 150°C, which could destroy the sensor. The software reverts the pump to fully on if this happens, but the system fault may prevent the system cooling down the panel. To get around this you will have to consider the sensor as a 'throw away' in the rare case of such a fault or switch to a PT1000 type sensor for evacuated tube systems.

Temperature sensors

The five temperature sensors are used for:

Panel: Determines pump on/off
HWC Top: Info only (optional)
HWC Middle: Controls backup-up heating.
HWC Bottom: Used in differential mode to compare against the panel sensor to control pump on/off. Also used to decide if the panel is exporting heat.
Aux: Anything you want – controls an auxiliary relay.

If your HWC is small or your daily demand for hot water is high (a whole tank full or more) then the middle sensor can be deleted and the bottom one used instead. On the author's system the tank is 200 litres and half a tank is enough for daily use, so the backup heating only heats the top half.

Table 1: PV voltages

PV volts	Dull winter day and no sun	Full summer sun
Open circuit	15V	20V
With controller connected	11V	20V
With pump on and controller connected	4V(Note 1)	15V

Note 1: Pump will not run at 4V, but consumes current so software turns it off. But it would be 4V if it were on.

PV panel

The output of a PV panel is not like a battery in terms of V/I characteristics. It needs special consideration, especially to derive the correct sunshine level. Table 1 shows some details. Some solar pumps have inbuilt firmware that optimises the V/I draw of the pump to match the panel. For instance, some Laing DC pumps adjust this every three seconds.

It can be considered as a nearly constant voltage (20V) supply at most light levels, with an internal resistance that becomes higher as light level falls. Thus, with an open circuit panel it will produce high voltage over all light levels down to nearly dark; the voltage/light characteristic is highly non linear.

In order to provide a distinct difference between night and day voltages, it is necessary to lightly load the panel. This has no real effect on daytime voltage output, but at night it drops the voltage right down. A 1kΩ load is about right for a 12V 5W panel. The standard supply current for the controller and battery is enough load.

However, older Solartwin PVs already have a 330Ω resistor across them mounted in the black plastic termination box behind the PV, and this needs to be removed first as it provides too great a load, preventing the panel from charging the battery on dull days. Check newer panels for such a resistor and remove it.

Relay load

The relays, even though they have an 8A/230V AC capacity, are only safe to drive less than 5A when mounted on the PCB, as the copper tracks may not take a full 8A without reinforcement.

Components

Optional components are marked in the Parts List with * or **. Any marked **, if not fitted, need to be replaced with a wire link. Leave some or all out if you don't need:

Relays
Buzzer
LED
Lightning protection
Auxiliary sensor
Reset switch
The ISCP port (CON1)

The software will not notice they are missing, with the exception of the Aux sensor, which will be shown as short circuit if replaced with a shorting link.

Most of the components are easy to buy, especially if you have access to Farnell or RS Components. The author (contact him through *Chat Zone's Shop Talk*) should be able to supply components if you are unable to source them.

Software

The software has these main functions:

- Differential or fixed temperature level control
- Display of five temperatures and sunlight level
- Solar-based clock
- Storage of kWh input from panel and display of day/week/month cumulative input statistics
- Error report if a temperature sensor fails
- Power saving mode during darkness
- Control of backup water heating and an auxiliary relay
- Weekly check to ensure temperatures have been high enough to kill Legionella.
- Calibration of temperature sensors
- Reset

In normal operation, the software uses a nested series of timed loops that every:

Five seconds, changes the screen to display different variables, cycling round all the temperature, voltage and power readings in six steps.

30 seconds, restarts screen cycle.

One minute, reads all A/D inputs and recalculates the average light level. Switches pump on or off. Decides if it is dawn or dusk. Logs the panel power output. Changes Aux relay state if needed.

One hour, reads an internal accurate clock and corrects the hour derived from the approximate six second clock. Sums the power output for the hour.

24 hours, corrects the time at about midnight to 'true' midnight. Sums the power output for the day.

One week, sums the power output for the week

One month, sums the power output for the month

There are two variants of the displayed items. In normal mode, temperatures and kWh are displayed. On the maintenance display, temperatures and the clock, with both the adjusted and non-adjusted values of time, are shown.

Clock

The five seconds is approximate and, as it is based on a software delay routine, it will slow slightly when extra software routines are executed. The one hour is fairly accurate, since it is based on a Timer Interrupt. But over time it drifts slowly, like most clocks, so the software corrects the clock back to 'true' midnight every night.

This is done by measuring when a certain low light level threshold is passed in the morning and evening and assuming these are dawn and dusk. 'True' midnight is assumed to be half way between them, although in reality it varies a little depending on the time of year. Heavy averaging is performed on dawn, dusk and midnight corrections as weather changes alter the time when the threshold is passed.

Daylight saving time

No correction for Daylight Saving Time (DST) is made automatically, but you can set it via the menus. You can also add an offset to the minutes by menu because, unless you live exactly on 0, 15, 30, etc. degrees longitude, the solar minutes don't match your watch's minutes. In Wimborne solar time is about 10 minutes behind GMT. You can also use this offset to cancel out the effects of a hill or house asymmetrically shielding your PV from morning or evening light, although it triggers on diffuse light before sunrise and after sunset rather than direct sunshine, so it is not very sensitive to shading.

A ±10 minute accuracy is achievable once the offset is derived. The prototype in southern England was found to be within five minutes in winter, but up to 20 minutes slow in summer so adding 10 minutes to the offset would bring it to ±10 minutes. It will be different from 20 minutes in other countries. Although it is not accurate compared with a digital watch, it never needs adjusting as it is always being corrected, apart from for DST.

It is an adequate clock accuracy because the only function that uses the clock is the backup heating and this does not have to come on at exactly the right minute every day. Other functions just need to know that a day has passed, so a new log of kWh can be started for the next day.

In use, start with an initial minute offset = – (4 × degrees east of 'correct' longitude) +10 (half the 20 mins above). Also, adjust the DST hours if you live in a country whose time is not correct for the longitude, but use the minute offset instead if it's less than one hour out. After a week of running you can see if you have got it about right, but it takes a full year to calculate the offset to a few minutes accuracy.

Dull days

The pump is not switched on if the PV is below 6V (selectable), this ensures that on dull winter days all the PV output, less the 2mA for the controller, goes to charging the battery rather than attempting to run the pump, which would significantly lower the PV voltage see – Table 1.

It also makes measuring dawn and dusk easier as the difference between full moon voltage and a dull daylight is larger if the stalled pump is not loading the PV. It is suggested you measure the full moon voltage and then daylight on a very dull winter day at mid-morning and set the dawn threshold half way between. This is about 2V for a Solartwin panel with integral resistor and 4V if the resistor is removed, both still loaded by the controller.

Ensure that no streetlights, car headlights or security lights regularly fall on the PV panel. It can accept short bursts of light, as calculations are performed not with the instantaneous light level, but averaged over a few minutes; so a short burst of light from headlights should not alter this average much.

Logging of power input

Some expensive commercial controllers provide logging of kWh collected from the panel. This is done using the equation:

Instantaneous kW = constant × flow rate of coolant × temperature difference across panel.

Where constant depends on the specific heat capacity and density of the coolant. There are menus to enter the percentage of and type of antifreeze, as this affects this constant.

The biggest drawback of this is that a flowmeter is needed, which is an expensive item outside the cost range of this project. So, instead, we make some approximations to come up with the same answer without the flowmeter, by using the pump voltage to give the flow rate.

These readings should only be taken as approximate, say ±50% unless you can properly calibrate and programme in the flow/voltage characteristic of your pump, which has not been fully done in the supplied software for the Solartwin pump.

To improve the accuracy you need to disconnect the pump and measure the flow into a bucket over say one minute at various pump voltages, using the normal backpressure that the system works at. Also, find out the specific heat capacity of your coolant. Use these values to derive a new constant in the equation.

The software measures the instantaneous kW every minute and provides a reading of total kWh per day, week and month. A warning message is displayed rather than the total if it has not collected enough readings since the last reset.

Backup heating

Backup heating is turned on at a set time every evening, on the hour, for up to a settable 59 minutes. Software is configured so that the time is delayed by one or more hours if the set hour falls within a period when there is still a lot of sun. For example, if you set the hour to 5pm it will be delayed to say 7pm in summer, depending on the light level. Use your normal central heating or immersion timer to give more heating if you need it; some may like a short morning or midday boost.

Sunlight prediction

If you live in a climate that is fickle, like the UK, it would be useful to be able to predict how much sun is coming tomorrow; then a decision can be made about how much backup heating to apply each evening. This is because there is little point in fully heating up the HWC with backup heating, then using little water that night, which wastes the sun the next day because the tank cannot absorb much more heat.

Barring a connection to the controller over the internet/phone to a weather forecasting service, how can such a forward prediction be done? The software makes an assumption, if the economy mode is set, and there has been a good amount of sun over the last few days then there is a reasonable chance that tomorrow will be sunny. So it reduces the temperature to which the backup heating heats by a settable amount.

This mode has some downside in that if there is heavy use of hot water before the next evening or there is no sun the next day, then the hot water may run out. But 'ecowarriors' will be prepared to accept the odd time that the water gets cool, and you can always make the boiler top it up on a manual boost.

If you want an even more extreme economy setting, then make the backup heating only sense off the top sensor, so it's only heating a small part of the tank. This economy mode works best if your HWC is large.

Legionella

To kill off Legionella bacteria it's recommended to heat the whole HWC up to >60°C daily, or at least once per week. Here it's set to once per week. This day will always be the day of the week after the one on which you reset the unit. So, if you want it always to be heating on Friday night, so you can have extra hot water at the weekend, then do your reset on a Friday.

It uses the bottom sensor for measurement, so check that there is not a huge variation in temperature in the tank with the top becoming dangerously hot to get the bottom sensor up to the threshold. Using the middle sensor with software changes is an alternative, but it will not heat all the tank.

Auxiliary relay

The auxiliary relay is changed over if the Aux temperature sensor goes below a settable value. The hysterisis is settable too. It can also be set to change over on a rising temperature. Like all the other sensors it is read every one minute (except at night) and the relay operated for not less than one minute.

The buzzer comes on if it is enabled and the temperature rises more than 3°C (settable) above the set point. Or, if it is set to sound on a falling temperature that's 3°C below the set temperature. This is useful as a frost-stat for greenhouses, with the Aux relay powering a small heater. The pulse-width on the buzzer is very short for this to avoid using too much battery power at a time when the sun may not be shining.

Useful Suppliers/Information

Some useful websites:

www.solartwin.com Tel. 01244 404 410 (See their advert on page 45 in this issue)

www.solarpanelsonline.co.uk – CPS Solar, supplier of PV panels

www.acs-solarsystems.com/solar_pumps.htm

www.alternativeenergystore.co.uk/item/item/103001/1/0/Laing-Eco circ-D5-Solar-DC-Pump.htm

Some of the above supply Laing low voltage DC pumps.

http/stores.ebay.co.uk/Charles-Austin-Pumps. The Charles Austin DL2 pump is similar to that used in the Solartwin system less the brushless motor and pressure release valve, so it will not survive freezing.

A number of other suitable pumps are available from many sources such as eBay if you search for 'solar pump'. Many will not survive freezing, so the pump and system need to be frost protected.

Pre-programmed PICs are available from the author or from Magenta Electronics – see their advert in this issue for contact details.

The PIC program can be downloaded from the Library in the *EPE* website at **www.epemag.com**

Settable values

There are over 30 settable values that can be set with software by pressing the Menu button. Due to code and LCD size limitations it has not been possible to build in full text labels for these, but there is a file called **Menu_value_labels.doc** on the *EPE* site that list them with possible ranges of values.

We have not tested all the possible values, so take care if departing significantly from the default values. These values are stored in non-volatile EEPROM in the PIC, so will not reset to defaults if power is lost or the PIC is reset unless you request it.

There are other values that could be changed if you care to amend the software.

Power saving

To reiterate, saving supply power, especially after dusk and from the battery, is a critical feature of the design. Some readers may like to use some of these ideas in designing their own circuits. This saving is done by hardware and software measures as follows in roughly descending order of power saving:

1) Use latching relays rather than conventional relays
2) Use a low speed 250kHz clock.
3) Turn off the LCD supply after midnight
4) Use 3.6V direct instead of the more usual 5V regulated (also saves the loss in regulators).
5) Turn off the PIC A/D when not actually sampling
6) Use an 18LF2520 PIC instead of the more common 16F876.
7) Supply the FET driver IC from the PV rather than the battery.

Part 2, next month, will cover the assembly, testing, connection and calibration of the controller.

Acknowledgements

The author could not have designed this controller without the unstinting support of several people, especially the Matrix Multimedia *Flowcode* support team, including Ben Rowland and Steve Tandy, who baled him out when he got stuck with the software design. Thanks to the *Chat Zone* contributors who helped with ideas and the *EPE* team who converted it into an article.

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PIC-based MIDI Handbells
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Recycle It!

BY JULIAN EDGAR

Building a human-powered LED torch for next to nothing

Would you like to have a torch where you wind a knob just a few times and a white LED stays on brightly for two minutes and then remains visible for hours?
Well you can, and the only parts that you'll have to buy new are the LED and the box to mount everything in.

YOU'LL NEED A VARIETY of components from different salvaged goods to make this design, so it's one to keep in mind as you collect bits and pieces over time.

First, you need the turntable motor from a microwave oven. This is an AC synchronous motor that's about 20mm high and 50mm in diameter. In addition to the motor, inside the package is a system of plastic reduction gears that normally gives an output shaft speed of just 5 RPM (or thereabouts). By turning this shaft with a knob, it's possible to easily generate up to several hundred volts AC output! There's our power source.

WARNING! Exercise extreme caution when salvaging parts from a microwave oven. The large capacitors in the EHT (extra high tension) power supply can retain a lethal charge, even after the power has been switched off.

The primary components needed are the turntable motor from a microwave oven, an old plugpack and some high-value, low-voltage capacitors. These salvaged parts shouldn't total more than a few pounds, but do be careful when salvaging the turntable motor – the bite from the EHT circuitry in a microwave oven can be lethal, even with the power off (see warning in article).

Although these capacitors should be discharged by bleeder resistors when power is removed, don't take it for granted. Older microwave ovens may not be fitted with bleeder resistors, or the resistors may have gone open circuit. **For this reason, always make sure that the capacitors in the EHT supply have been discharged before removing parts from a microwave oven.**

Plugpack bits

Next, a small transformer is need to step that voltage down to something that can be rectified (ie, converted to DC) and used to drive an LED. This can be done using one or more diodes or a bridge rectifier. And guess what – inside any older plugpack you'll find just those components, already wired up and ready to go!

Do not pick a recent lightweight plugpack, – these use switchmode circuits that will not work in this application. You can recognise a switchmode design by the large number of internal components.

We tried a variety of older 230V plugpacks with transformers, and those with nominal outputs in the range of 6V to 12V DC all worked well.

Energy storage

To store the power you've generated, you need lots of electrolytic capacitors (we used seven in the prototype). In addition to being small enough to fit inside your chosen box, these should have as much capacitance as possible, while having a voltage rating of about 10V to 16V.

Several 10,000μF 10V capacitors are ideal, for example, but it doesn't matter if you use 10,000uF 16V caps instead. Electrolytic capacitors are used in nearly every piece of discarded electronics equipment – always keep an eye out for large-value low-voltage units to salvage.

While it looks as though the parts might cost a fortune, all you need to buy are the high-brightness LED, the box and possibly the trimpot. The alternator and gearbox come from a discarded microwave oven, the transformer and rectifier diode from a salvaged plugpack and the capacitors from a wide range of junked electronic equipment. This 'luxury' version also includes a neon lamp (salvaged from a cooker top) and a lens from a discarded video camera.

Warning!
The output of a focused beam or Luxeon Star LED torch is sufficient to cause eye damge.
Do not look directly into the torch, and don't shine the beam into anyone's eyes at a close distance.

A 10kΩ to 100kΩ trimpot (preferably multiturn) will make it easy to set the LED current. Again, these can be salvaged from lots of gear, but failing that, they are cheap to buy new.

Another essential item is a suitable knob, so that the shaft of the motor/gearbox can be turned by hand. This knob will need to fit a D-shaped shaft, and if you can't salvage one for nothing, you're not really trying!

White LED

You also need a white LED and this will probably have to be purchased. A 5mm high-brightness white LED works well. However, if you want more light output and are prepared to turn the knob more often, higher-rated units can be used.

For example, with this design, a 1W Luxeon LED can be strongly illuminated, although not to full brightness. Even so, do NOT look directly into the torch beam at close quarters.

However, the more powerful the LED, the shorter the time the capacitor pack will keep it on after you've stopped turning the knob. With the 1W Luxeon, the capacitor pack will drive the LED for less than a second, so in many ways a lower rated LED is more practical. (Note: if you use a powerful LED, you should uprate the power rating of the current limiting resistor (trimpot).)

Finally, if you want to build a 'luxury' model, you'll need a lens (one salvaged from an old video camera is perfect) and a neon indicator from an old oven or cooker top (hob).

Building it

To allow testing, roughly assemble the electronic circuitry for the torch on the bench before building the final version into a box.

The first step is fit the knob to the motor's shaft. In my case, I used a knob taken from the dashboard heater controls of an old car.

That done, connect a multimeter, set to AC volts, to the output of the motor (now working as an alternator). Now turn the knob, ***but make sure that you're not touching the output terminals***. You should get a no-load output of 100V to 200V, depending on how fast you turn the knob. If you come in contact with the output when you are turning the knob, you will give yourself a nasty shock, so be careful!

You should ***never*** try to wind the knob flat out – you'll strip the gears inside if you do. Instead, just turn the knob progressively and evenly at a slow speed (the optioned-up model has this aspect covered).

Plugpack

Before pulling the plugpack apart, follow this simple procedure to check that it is suitable. First, connect the plugpack's mains input terminals to the alternator's (motor's) outputs

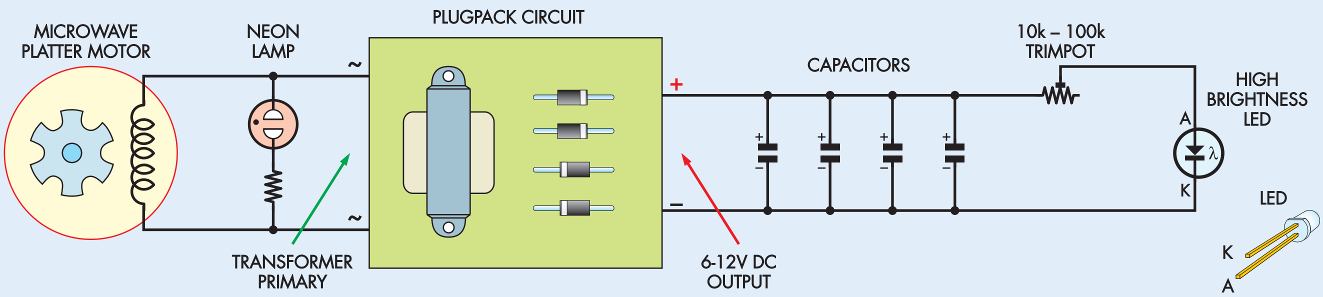


Fig.1: a salvaged microwave turntable motor is used as an alternator to generate high-voltage AC. This is then fed to a plugpack transformer and rectified to produce 6-12V DC by the innards of a plugpack. The capacitors are used for energy storage, while the trimpot allows the current through the LED to be adjusted to its rated value (or less).

Here's the 'basic' version. It's pretty simple to look at, but by turning the knob a few times, you can have the LED shining brightly for about two minutes and then remaining visible for hours.

This is the 'luxury' version. Again, it's just a matter of turning the knob a few times to get the LED shining.

(polarity doesn't matter). That done, connect the plugpack's output to the capacitor pack, taking care to connect the negative output lead (usually black or non-striped) to the negative side of the pack.

Now connect your multimeter (set to DC volts) across the capacitor pack and turn the knob. You should be able to read a voltage that gradually rises as you keep on turning. Any voltage from about 6V to 12V is fine.

The trimpot (wired as a variable resistor) and the LED can now be added to the circuit. The circuit will look like Fig.1, except you have to add your multimeter to measure the LED current. To do this, simply 'connect' the multimeter (set to milliamps DC) in series with the LED.

Set the trimpot to its highest resistance and turn the alternator knob 10 times. It's then just a matter of slowly adjusting the trimpot until the maximum current rating of the LED is reached. For example, if the maximum current rating of the LED is 100mA, set the trimpot to provide this current flow. Check that further turning the alternator knob doesn't cause the required value to be exceeded.

Alternatively, you may want to set the trimpot so that the LED operates at less than full brightness, so that it stays on longer after you stop turning the knob.

Final assembly

The plugpack can be opened to retrieve the parts by crushing the case slowly in a bench vice until it cracks. That done, you can build the unit into an off-the-shelf plastic box. Seal the box (eg, with silicone sealant) if the torch is to be used in the rain or in wet areas.

And the 'luxury' model? Well, it includes a neon lamp wired straight across the alternator. This lights at any voltage over 70V to 100V (the voltage depends on the neon lamp) and so it's a good guide as to when the knob is being turned quickly enough to generate sufficient power. In practice, it should only just light.

Neon indicators salvaged from ovens and cooker tops usually have a series resistor built into their bodies, in which case you can just wire it straight in.

The second option is to add a lens. Our prototype used a video camera lens, supported by a cut-down section from a Portaflood light. This is ideal if you want a long narrow beam – the prototype has a beam range of at least 100 metres!

Other versions

In the Sept '06 issue of *EPE* we covered a different design for a human-powered torch. That approach used a direct-drive stepper motor as the power source.

So what are the advantages of taking the approach shown here? Because of the built-in gearing of the microwave oven motor, you can generate much more power in a shorter time – just a few turns of the knob will keep the LED brightly lit for a reasonable period.

However, the use of a gearbox also has downsides – when being wound, the torch is noisier than a stepper motor design and the plastic gears have a finite life.

Rat it before you chuck it!

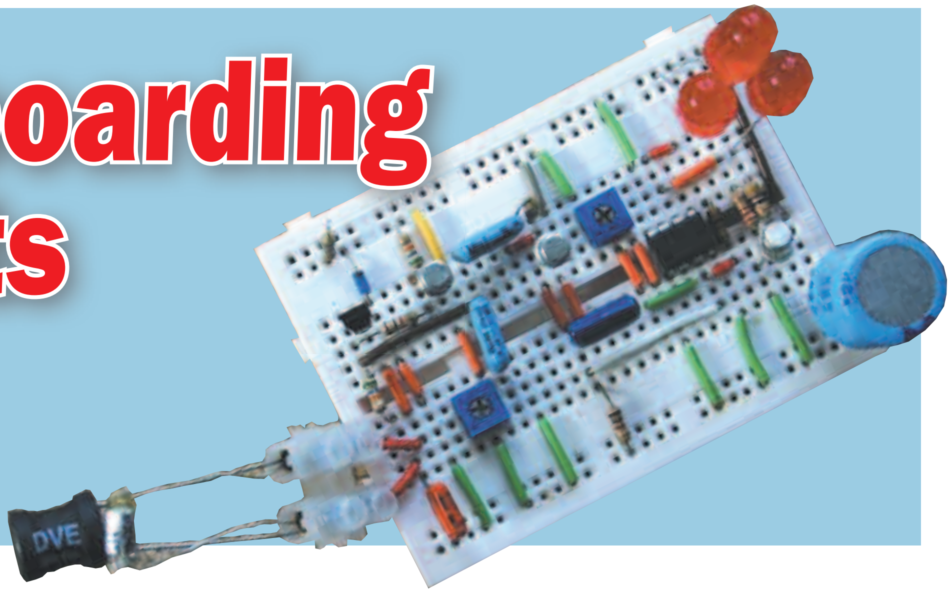
Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you think that surely there must be some good salvageable components inside? Well, this column is for you! (And also for people without much money.) Each month, we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

And you can contribute too. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you have a use for the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up but you get the idea . . .)

If you have some practical ideas, write in and tell us!

Breadboarding Projects

by Dr Malcolm Plant



A beginner's guide to simple, solder-free circuit prototyping
Part 9: Lightning Detector

This month we use a three-lead AM 'radio-on-a-chip' to detect the presence of possible lightning discharges and thunderstorms.

Project 16:
Lightning Detector

You probably know that lightning discharges cause amplitude modulated (AM) radio receivers to crackle with radio interference. The discharges generate radio waves that interfere with regular radio reception on AM wavebands. This circuit provides a visual sign of these dishcharges by turning on a light-emitting diode (LED).

The circuit responds not only to lightning discharges from local thunderstorms, but also from those active many miles away. You may say that this project has no great practical value, but it's not without interest to weather amateur forecasters. To see the LED flash in response to distant lightning strikes certainly appeals to the author!

Circuit diagram

The Lightning Detector circuit shown in Fig.9.1 essentially comprises four building blocks: long-wave radio receiver, transistor amplifier, comparator, and a visual display driver. The central component for the first building block is an integrated circuit, IC1, a 'radio-on-a-chip' fed by

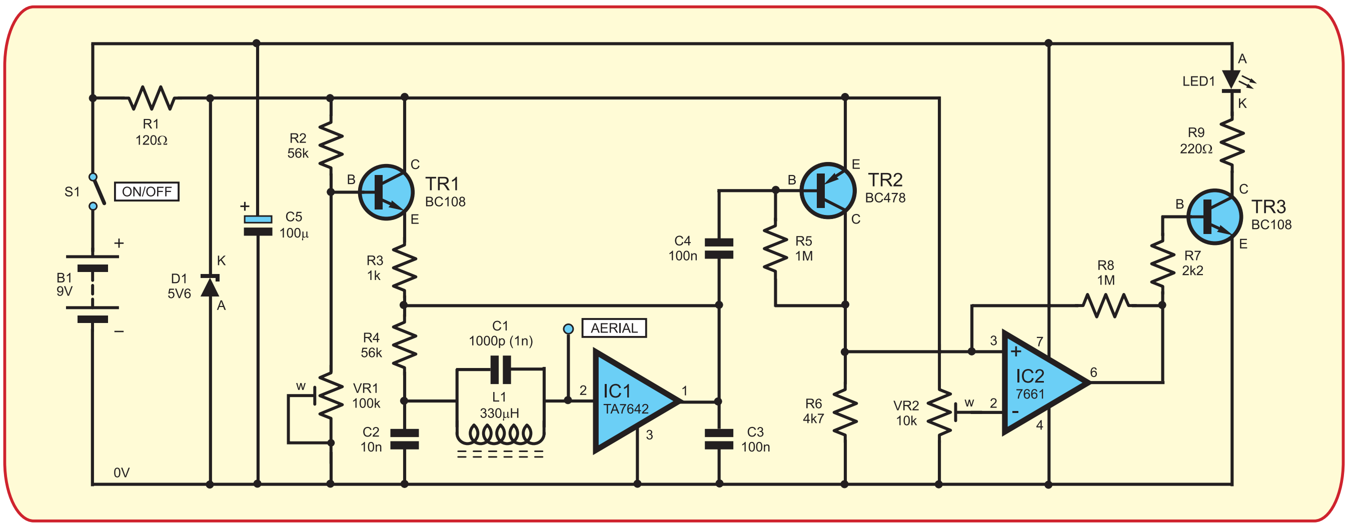


Fig. 9.1. Complete circuit diagram for the 'breadboard' Lightning Detector

a tuned circuit comprising inductor L1 and capacitor C1.

IC1 requires a 1.5V supply voltage, which is provided by transistor TR1 and its associated resistors plus preset potentiometer VR1 (wired as a variable resistor). Adjustment of VR1, and hence of the voltage supplied by TR1, alters the sensitivity of the tuned circuit. Essentially, IC1 amplifies the radio frequency signals when the tuned circuit (L1, C1) resonates in response to receiving the radio waves from a lightning discharge, and delivers an AM audio frequency signal at its output.

The values of L1 and C1 were chosen to make the tuned circuit resonate at about 300kHz, which is a key radio signature produced by a lightning discharge. The frequency, f_o, at which the parallel tuned circuit, comprising inductor L1 and capacitor C1, resonates is given by the equation:

$$f_o = 1/2\pi\sqrt{LC}$$

Using the values of L1 and C1 in the circuit:

$$f_o = 1/6.28\sqrt{330\times10^{-6}\times1000\times10^{-12}}$$
$$= 1/6.28\times10^{-7}\sqrt{33}$$
$$= 10^{7}\times0.03 = 300\text{kHz}$$

This is the principal frequency generated by a lightning discharge and the circuit is therefore 'tuned in' to this frequency.

Components needed...

Lightning Detector

Integrated circuit, IC1: type TA7642 AM radio IC
Integrated circuit, IC2: type 7611CMOS operational amplifier (op amp)
Transistors, TR1, TR2 and TR3: type BC108 or similar in a TO18 style package (TR1, TR3); type BC478 *PNP* low power or similar in a TO18 package (TR2)
Inductor, L1: value 330µH, type SRL334 radial lead format
Diode, D1: 5.6V 400mW Zener diode
Light emitting diode, LED1: 5mm any colour
Potentiometers, VR1 and VR2: *values 100k*Ω (VR1) and 10kΩ (VR2), miniature preset types
Capacitors, C1 to C5: values 1000pF (1nF) polystyrene or mica (C1); 10nF polyester (C2); 100nF polyester (C3, C4); 100µF 16V radial elect. (C5)
Resistors, R1 to R9: values 120Ω (R1); 56kΩ (R2, R4); 1kΩ (R3); 1MΩ (R5, R8); 4.7kΩ (R6); 2.2kΩ (R7) and 220Ω (R9).
Switch, S1 (On/Off): single-pole, single-throw (SPST)
Battery, B1: 9V and connecting leads
Protobloc, 150mm length of 0.6mm dia. insulated wire, ends bared, for 'aerial' – see text, wire links and a 2-way screw terminal block (TB1)

Audio signal

The second building block uses *PNP* transistor (TR2) to provide an amplified audio frequency signal across resistor R6. This signal is then fed to the third building block based on the operational amplifier, IC2, wired as a voltage comparator.

The audio frequency signal at the non-inverting input (pin 3) is compared with the set voltage on the inverting input (pin 2). When the amplitude of the audio frequency signal on pin 3 rises above that on pin 2, the output voltage from pin 6 of IC2 rises rapidly aided by the positive feedback provided by R8.

In the fourth building block, transistor TR3 switches on and off as the radio frequency signal from the lightning flash is detected and fades, causing LED1 to flash in response.

Breadboard

The Protobloc component layout for the Lightning Detector circuit is

Construction brief

To ensure trouble-free assembly, you should try and follow these basic guidelines

Always use single-core 0.6mm diameter plastic-sleeved wire for wire links, not thicker. The ends of the wire should be stripped of plastic for about 8mm. The use of thicker wire can permanently damage the springy sockets underneath each hole.

Never use stranded wire; it can fray and catch in the sockets, or a strand can break off and cause unwanted connections below the surface of the breadboard.

It is very important to make sure that the bared ends of link wires and component leads are straight before inserting them into the breadboard. Kinks in the wire will catch in the springy clip below the socket and damage it if you have to tug to release the wire from the holes.

Make sure that the arrangement of components and wire links is tidy, with components snugly fitting close to the surface of the Protobloc. This usually means providing more link wires than is perhaps necessary, so as to avoid having wires going every-which-way across the board.

Never connect the battery leads to the top and bottom rails of the breadboard until you have carefully checked that all the component connections correspond to those on the circuit diagram.

Some components, such as switches and relays, do not have appropriate wire leads for insertion into the Protobloc. If you have access to a soldering iron, solder short lengths of single-core 0.6mm diameter plastic-sleeved wire to the terminals of these components.

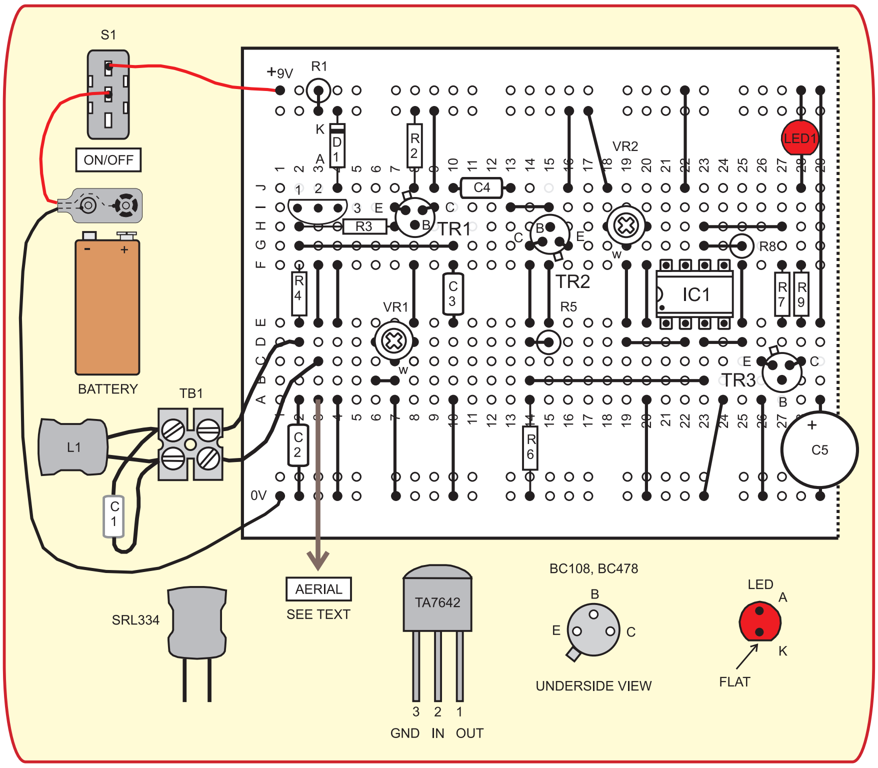


Fig. 9.2. Assembly of the Lightning Detector on Protobloc

shown in Fig. 9.2. The circuit needs an aerial, which can be a 150mm length (maximum) of 0.6mm diameter insulated wire, ends bared, and one end inserted into the breadboard, as shown in Fig.9.2 above.

Do not use a longer wire and NEVER connect the circuit to an outside aerial in case thunderstorms are nearby.

Notes

● Inductor L1 and capacitor C1 are connected in parallel and comprise the tuned circuit. Connect them together using a two-way length of terminal block to which are fixed two short lengths of insulated 0.6mm diameter single strand wire for insertion into the breadboard.

● Resistor R1 and Zener diode D1 stabilise the power supply voltage to the first three building blocks which, in turn, stabilise the settings of VR1 and VR2.

● Once connected to the battery, the circuit needs two adjustments provided by presets VR1 and VR2. First adjust VR2 until LED1 just goes out; that is the voltage on pin 2 of IC2 is just above that on pin 3. Next, adjust VR1 to the point where LED1 just stops flickering.

● You may use a cluster of three LEDs to enhance the display but make sure all the LEDs are the same type.

● When setting up and using the circuit, you should keep the circuit away from other electronic devices, such as mobile phones and computers, as they can cause the LED to flicker, masking anything that might be of interest.

● Rather than waiting for a thunderstorm to check whether the circuit responds to a lightning discharge, there are couple of tests you can try. First, switch a wall light switch on and off and the radio waves generated by the sparks at the switch contacts will cause LED1 to flash.

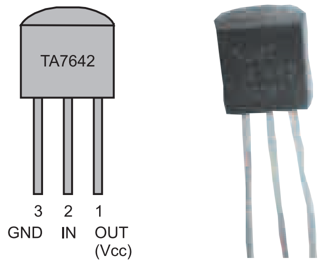
Alternatively, comb your hair briskly with a plastic comb so that it becomes electrically charged, then hold the comb near the tip of the aerial. Sparks jumping from the comb to the aerial will cause LED1 to flash.

Now keep an eye and ear open for a thunderstorm near or far when LED1 will flash dramatically.

Next Month; a low-budget AM Radio

Component Info

IC1, type TA7642 AM radio IC



With the flat face facing you, pointing down, the pin functions are shown above.

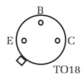
IC2, type 7611 CMOS op amp

PIN 1

Viewed from the top, an indented dot and a 'half-moon' shape at one end indicate pin one. The pins are numbered anti-clockwise ending at pin 8 opposite pin 1.

TR1 and TR3, type BC108 (*NPN*)
TR2, type BC478 (*PNP*)

Seen from below, the emitter lead is next to the small metal tag. Clockwise from the emitter are the base, and collector leads.



L1, type SRL334 330μH inductor, radial lead format

To be connected in parallel with capacitor C1 to form a 'tuned circuit'

VR1 and VR2, potentiometer

This is a preset type that can be inserted directly into the Protobloc and its value adjusted with a small screwdriver

INTERFACE

By Robert Penfold

PORT OF CALL

As discussed in numerous previous *Interface* articles, the so-called PC legacy ports, such as the serial and parallel types are being phased out, and to a significant extent they have become obsolete already. This became apparent when replacing two ageing PCs with new ones.

It was most obvious with the one that was obtained from one of the biggest PC manufacturers. Not only did it lack serial and parallel ports, but there were no PS/2 mouse and keyboard ports either. In order to use my high quality and expensive PS/2 keyboard with this computer it was necessary to use a PS/2-to-USB adapter.

Optional ports

The situation was different with the second PC, which was put together from individual components. There are still plenty of PC motherboards available that have a serial port, a parallel port, or even both. The board eventually chosen did not have either, but it did at least have both PS/2 ports.

As pointed out in the past, even if a motherboard lacks any legacy ports in its compliment of built-in connectors, it might still include the necessary hardware for one or more of these ports. The Gigabyte motherboard used does actually have the hardware for a serial port, and it is accessible via a small connector on the board (Fig.1).

In order to use a port of this type it is necessary to obtain the optional bracket and lead. The bracket fits in place of the back plate behind a vacant PCI expansion slot, and with the lead connected to the motherboard the port is ready for use.

In practice it might not be quite that easy, since the BIOS might have the port disabled by default. In fact, it will almost certainly have any optional ports disabled by default. The port is certainly not active if there is no sign of it in Device Manager or the Windows System Information program It will then be necessary to go into the BIOS Setup program by pressing the appropriate key (usually Esc, Del, or F2) just before the computer starts to boot into Windows. The ports are usually handled by the Integrated Peripherals section of the BIOS Setup program.

It is sometimes possible to select the port address and other settings, but these days it is more likely that these will be handled automatically, and it is then just a matter of altering the setting that switches the port on and off. Remember that changes must be saved on exiting the Setup program or they will not be implemented.

One problem in implementing one of these optional ports is that the back plate and lead can sometimes be difficult to obtain. Also, the economics of modern computing is such that a USB serial port adapter might cost less than a simple bracket and lead. A USB serial port adapter could therefore be a cheaper and easier solution.

On the other hand, the built-in port is a normal serial type that is fully compatible with old software and operating systems. It will work with MS-DOS and GW BASIC, Windows Vista and Visual BASIC 2008, or anything in between! The same cannot be said for serial and parallel ports provided by a PCI card or a USB adapter.

Receiving serial data

The subject of writing data to a serial port using Visual BASIC 2008 Express Edition was covered in a previous *Interface* article. Here we will consider reading text strings from a serial port.

The MSCOMM component used with Visual BASIC 6 is not available in later versions of Visual BASIC, but in the current version there is an alternative in the form of the SerialPort component. There are similarities in the way these two components are used, but there are also some differences, which is inevitable given the major changes to the programming language itself in recent years.

An important similarity is that the SerialPort component can be event driven. In other words, it is not necessary to have your program periodically check for new bytes or characters of received data. Instead, an event is triggered when data is received, and the software just has to

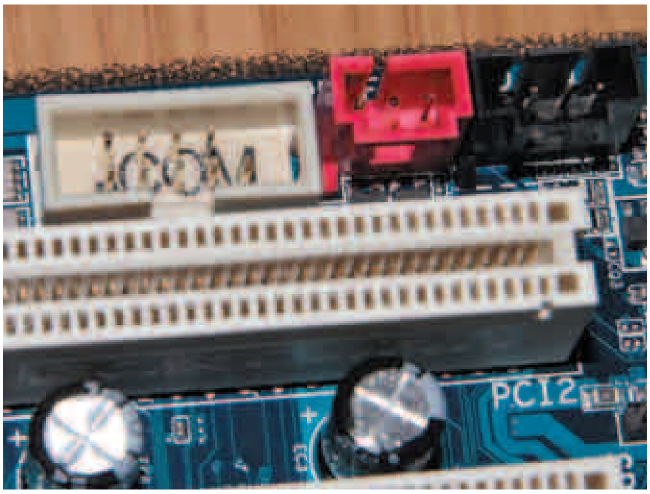


Fig.1. PCs sometimes have optional ports available on the motherboard, such as this serial port. An appropriate back plate and lead are needed in order to use one of these optional ports, and the port must be enabled in the BIOS Setup program

Listing 1

```
Imports System
Imports System.IO.Ports

Public Class Form1
    Dim WithEvents port As SerialPort = New _
     System.IO.Ports.SerialPort("COM1", 9600, Parity.
None, 8, StopBits.One)

    Private Sub Form1_Load(ByVal sender As Object,
ByVal e As _
                      System.EventArgs) Handles Me.Load
       CheckForIllegalCrossThreadCalls = False
       If port.IsOpen = False Then port.Open()
    End Sub

    Private Sub port_DataReceived(ByVal sender As
Object, ByVal e As _
       System.IO.Ports.SerialDataReceivedEventArgs)
Handles port.DataReceived
       TextBox1.Text = (port.ReadTo("!%"))
       If port.ReadExisting.Length = 0 Then
          ListBox1.Items.Add(TextBox1.Text)
       End If
    End Sub
End Class
```

include a routine to handle this type of event.

Most of the information about using the SerialPort component tends to be somewhat over involved and inappropriate in the current context, where masses of data in huge chunks are not normally involved. All that is normally required is a means of periodically reading and displaying a few bytes of data or a short text string. In this case, there is a notable exception in the form of a simple open source program to read strings from the serial port and display them. On the basis that there is no point in 'reinventing the wheel', a slightly modified version of this program is shown in Listing 1.

Users are free to use and modify the program very much as they like under the open source license. The only change I have made is to remove one line of code that seemed to be spurious and prevented the program from working correctly. The original article by Sigurd Johansen (which also includes a simple text string transmission program) can be found at: **http://69.10.233.10/KB/system/Serialport_COM.aspx**

Boxing up

If you try this program it is necessary to add a listbox component and a textbox type to the form, and these must be left with their default names or the listing must be modified to suit. Of course, a SerialPort component must also be added, but it will not be visible on the form. The function of the program is to display the last received text string via the textbox, and to show all the received strings in the listbox.

The first few lines of the listing initialise everything so that the main part of the program will recognise and use the serial port correctly. In particular, the port is declared using a Dim statement. This part of the program also sets the baud rate and word format for the appropriate port.

It is possible to control these using the Properties windows for the SerialPort component, but setting these parameters via the program ensures that they are always set at the correct figures. The settings in the program will override the default values or any set manually via the Properties window.

The word format is the usual one start bit, eight data bits, one stop bit, and no parity checking; while the baud rate is 9600. These can be changed to any valid settings, and a serial link will only work properly if both ends of the system are set for the same baud rate and word format.

The number of start bits in asynchronous serial communication is always one, so no start bit value is used in the program. It is assumed that the program will be used with serial port one (COM1), and this will probably be the case if a built-in serial port is used. Add-on ports usually have higher COM numbers though, and the number of the port can be found using the Windows System Information program.

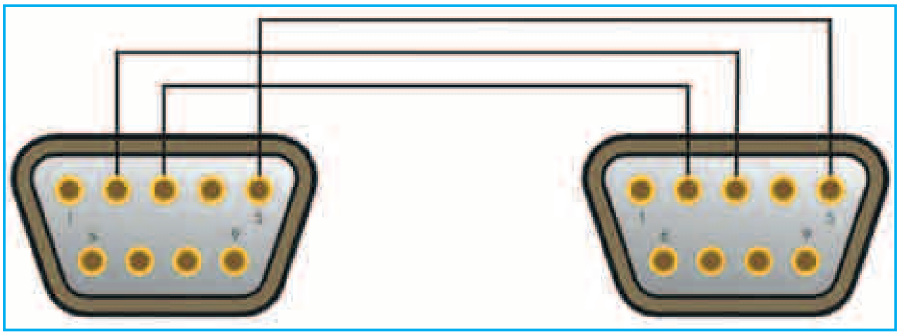


Fig.2. A null modem RS232C lead enables two PCs to communicate via their serial ports. This simple three-wire link provides two-way communications

In error

When experimenting with programs that read from the serial port, it is not unusual to have problems with error messages, due to a control being accessed by a thread other than the one that created it. The solution is to set the appropriate error checking to False so that it does not raise an error.

In a similar vein, a check is made to ensure that the port is not already open, and it is only opened if it is currently closed. This ensures that an error is not generated by an attempt to an open a port that is already open.

The rest of the program reads the received text strings and writes them to the textbox, overwriting any text that is already present. The complete string is then written to the listbox, where it is added to any text already present.

Rather than waiting for a certain number of bytes to be received, the "!%" combination of characters is used to mark the end of each string. This is achieved by using the ReadTo version of the port reading instruction, and specifying the required termination string in double quotation marks.

This is a more versatile arrangement that, within reason, can handle strings of any length. It can also accommodate strings of different lengths. In the current context the data contained in the strings will often be numeric characters from "0" to "9" and nothing else. A single non-numeric character could then be used to mark the end of each string.

An easy way to test the program is to connect the serial ports of two PCs using a simple null modem cable (Fig.2). One PC is then used to send data using the matching writing program, or any terminal program, and the second PC is used to receive the data. The cable can carry data in either direction, so it does not matter which PC is used to transmit data or which is used to receive it.

The program in action, after some text strings have been received, is shown in Fig.3. The program would almost certainly need a certain amount of modification in order to get it to work properly in a real-world application, but it provides a good starting point for a system that swaps data with a peripheral gadget based on a microcontroller.

Summing up

Swapping data in the form of text strings seems to be the preferred method with peripherals that are based on PICs or other microcontrollers, and it can have its advantages when the system must handle control codes and several types of data. It works less well with very basic interfaces that lack the 'intelligence' of a system based on a microcontroller. Since UARTs and similar serial interfacing chips are now largely obsolete there is usually no alternative to using a microcontroller for this type of interfacing.

However, unlike its MSCOMM predecessor, the SerialPort component has no problem handling bytes of data. Replacing the final subroutine of Listing 1 with the subroutine in Listing 2 results in the program reading individual bytes of data, and it displays the last received values in decimal form.

As one would probably expect, reading bytes of data is handled using the ReadByte version of the port reading instruction. The listbox component is not required with this version of the program and should be omitted. Using the SerialPort component, with a USB adapter to provide a suitable port when necessary, it is reasonably easy to accommodate very basic interfacing or more sophisticated arrangements.

Listing 2

```
   Private Sub port_DataReceived(ByVal sender As
Object, ByVal e As  _
     System.IO.Ports.SerialDataReceivedEventArgs)
Handles port.DataReceived
      TextBox1.Text = (port.ReadByte)
      If port.ReadExisting.Length = 0 Then
      End If
   End Sub
End Class
```

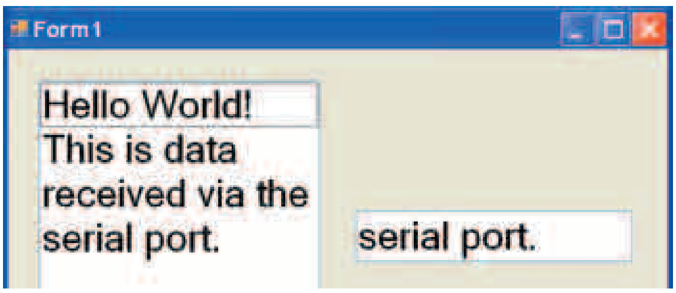


Fig.3. The program of Listing 1 in action. It is designed to receive text strings which can be any length but must be terminated with the appropriate two characters ("!%")

Triac fuses

Zack from Ontario, Canada emailed with the following question:

Regarding the STMicroelectronics data sheet on the BTA06 6A triac, it shows a term called I^2t value for fusing. What does this term mean and how can it be used correctly in a circuit to protect the triac?

Although the term I^2t relates more specifically to fuses than it does to triacs, we will take this opportunity to provide a basic introduction to triacs and related devices for the benefit of readers who are not fully familiar with them. We will then answer Zack's question.

The BTA06 is part of a series of triac devices from STMicroelectronics (**www.st.com**) suitable for general purpose AC switching of loads up to 6A. They can be used as an on/off function in applications (like a relay) or for phase control operations such as light dimmers and motor speed controllers.

Family characteristics

Triacs are a member of a family of devices that also includes diacs and silicon controlled rectifiers (SCRs). Schematic symbols for these devices are shown in Fig.1. All these devices are bistable, that is, they have two states of operation, with different levels of conductivity between the devices' two main terminals in the two states.

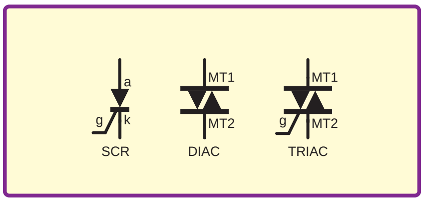


Fig.1. Schematic symbols

In the 'on' state they have a low impedance, which is maintained as long as the current through the main terminals remains above a certain limit known as the *holding current*, I_H. For the BTA06/BTB06 series, I_H ranges for 10mA to 50mA, depending on the device used.

In the 'off' state they have a very high impedance, which is maintained as long as the applied voltage is below a certain limit, above this point the device breaks down. This is used to switch on diacs (which have two terminals) but is avoided in SCRs and triacs, which are controlled using a gate (g) terminal. For diacs, this voltage is called the *breakover voltage*.

For triacs and SCRs, applying a sufficient pulse of current to the gate will switch the device into the 'on' state. Once in the 'on' state, the gate current is not required to be maintained due to the bistable nature of the device. After switching, they remain on until the main current falls below the holding current.

SCRs conduct in one direction and behave as reverse biased diodes in the other direction, for these devices, the main terminals are designated anode (a) and cathode (k). Other devices, such as diacs and triacs, conduct in both directions. Here the main terminals are simply called *main terminal 1* (MT1) and *main terminal 2* (MT2). Other terminal names are also used, for example A1 and A2 on the BTA06 datasheet.

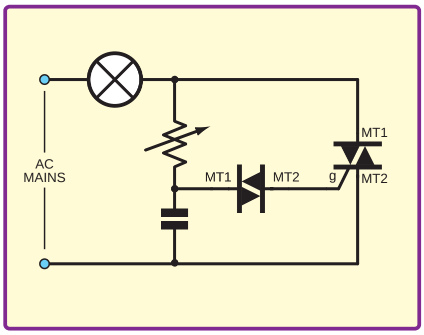


Fig.3. Lamp dimmer concept

An outline of a dimmer a circuit is shown in Fig.3. During each half cycle of the mains waveform the capacitor charges up at a rate

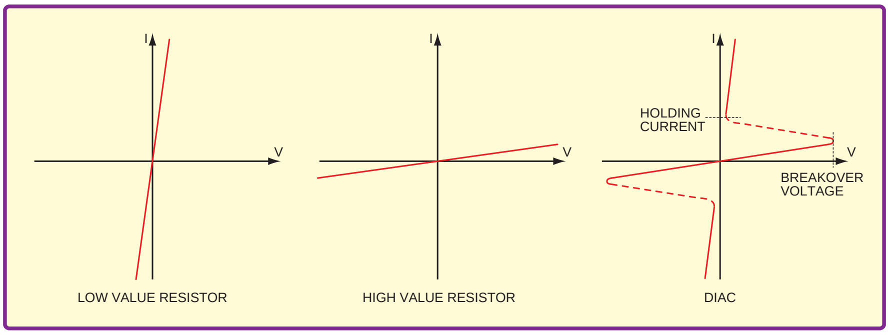


Fig.2. Plots of current against voltage for low value resistor, high value resistor and diac

Applications

The bidirectional nature of diac and triac operation means that they can be used to switch AC, whereas SCRs can only be used for DC or one half of an AC waveform. Triacs are often used for AC mains power control and switching.

In Fig.2 is shown a graph of current against voltage for a diac. For comparison the plots of a low-value and a high-value resistor are also shown. Notice how the diac switches from high resistance to low resistance when the breakover voltage is reached.

One of the most well known applications of triacs and diacs is in dimmer circuits for incandescent lamps. The triac is switched on part way through each half cycle of the mains waveform and hence supplies power to the lamp. The triac will switch off as the waveform crosses through 0V because the current in the device will fall below the holding current. Thus the earlier in each half cycle the triac is switched on the greater the proportion of time the lamp will be on and hence the brighter it will shine.

set by the variable resistor (potentiometer). When the voltage on the capacitor reaches the breakover voltage of the diac it will switch on sending a pulse of current into the triac. The triac and hence the lamp will switch on and remain on until the mains waveform crosses through 0V again.

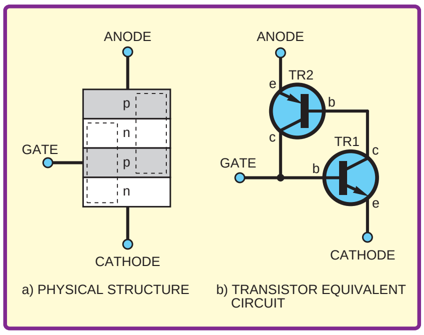
The diac's breakover voltage will be much lower than the mains peak voltage, a typical value would be around 30V. The triac's breakdown voltage will be higher than the peak mains voltage (a typical value would be 500V).

This circuit is for illustration only, as it lacks important features such as RF suppression, diac current limiting, and (where required) snubbing, and has relatively poor control, particularly at low power levels. Additional circuitry is needed for an acceptable performance.

Structure and operation

All these devices are based on a least four alternating layers of *p* and *n* silicon with at least three diode junctions. Fig.4 shows the structure of an SCR. It is constructed from four layers of silicon of alternating type (ie *pnpn* (*p*- and *n*-type semiconductor). Compare this with a bipolar junction transistor (BJT) which is a three-layer device – either *pnp* or *npn*.

The SCR is like two overlapping transistors – the *np* of a *pnp* transistor overlapping the *np* of an *npn* type, as indicated by the dotted boxes in Fig.4a. This leads to the transistor equivalent circuit in Fig.4b.



a) PHYSICAL STRUCTURE b) TRANSISTOR EQUIVALENT CIRCUIT

Fig.4. SCR structure and equivalent circuit

We can understand this behaviour by looking at the equivalent circuit of the SCR in Fig.4b. The 'trigger' gate current turns on transistor TR1. The collector (c) current of TR1 provides a base (b) current for TR2, turning it on too. In a similar manner the collector current of TR2 provides more base current for TR1 turning it on even more. This is a positive feedback effect that quickly ensures that both transistors are on. Once this condition has been triggered by the gate it is self-sustaining, so gate current is no longer needed.

The triac is a little like two back-to-back SCRs. It conducts in both directions and can in principle be switched on by a gate current of either polarity. This leads to four possible 'quadrants' of operation depending on the polarities of the gate current, I_G, and on-state current, I_T, as shown in Fig.5. However, not all practical devices can switch in all quadrants and triacs are not necessarily symmetrical across the quadrants in terms of sensitivity of triggering.

When a triac switches off, the current through it decreases and the voltage across it increases. There is a risk of spurious triggering of triacs after conduction if the slope of the decreasing current is too high or the slope of the increasing voltage is too high. This is characterised on the datasheet by the critical rate of decrease of commutating on-state current, (dI/dt)c, and the critical rate of rise of commutation off-state voltage, (dV/dt)c. By using an RC snubber circuit across the triac, the circuit rate voltage increase during switch-off is reduced, so reducing the possibility of unwanted triggering, but at the cost of extra components.

The BTA06 is an example of what STMicroelectronics call a 'snubberless' triac. It has an improved structure over a basic device, which results in an improved switching performance. These devices offer advantages in a number of situations: where the load is not well defined, so it is difficult to design a suitable snubber; in motor drive circuits, where the current rating of snubberless triacs can be much less than for conventional devices; and for loads which generate waveforms with very high rates of change of current, such as some inductive load configurations.

A consequence of the structure of these devices is that they will not trigger in quadrant four (Fig.3). However, this is not a problem as this form of triggering is rarely used.

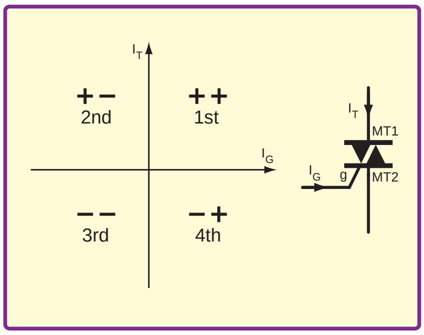


Fig.5. The four possible quadrants of triac triggering

Zack's question

Finally, returning to Zack's original question; there are a number of operating current rating for triacs:

$I_{T(RMS)}$ – On-state RMS current. The maximum RMS current for the device.

I_{TRM} – Repetitive peak on-state current. The maximum repetitive peak current for a specified pulse duration and frequency.

I_{TSM} – Non-repetitive surge peak on-state current. The maximum peak current under pulse conditions, defined for a single full cycle of a mains sinewave (20ms for 50Hz mains, and 16.6ms for 60Hz).

All these ratings are specified for particular temperature conditions and may vary with different device package types.

Protection

If the triac is to be protected from over-current by a fuse then it is not just the usual fuse current, but the fuse's I^2t rating (also known as the *Joule integral*) which must be considered. This is because the triac is a high-speed switching device which can handle, and is typically used with, high currents over short durations. The basic current rating of a fuse does not indicate how it will behave with very short, high current pulses and is, therefore, insufficient for determining the appropriateness of the fuse for the application.

If a fuse has a resistance of *R* ohms then the power dissipated in it by a constant current *I* is I^2R. If this current is applied for *t* seconds the total heat energy produced is I^2tR Joules. If this energy is sufficient it will melt the fuse. The fuse's resistance is fixed, but the *I* and *t* values are determined by the application (circuit under protection of the fuse), hence it is the I^2t value which is specified for the fuse.

In switching circuits in general we deal with pulses of current, so *I* will not be constant. Therefore, in order to calculate the energy, or I^2t value, it is necessary to integrate I^2 over the pulse duration time *t* (hence the term Joule integral). For specific waveforms, such as sinewaves, these integrals do not have to be calculated from scratch, for example $I^2t = 1/2\ I_{TRM}t_p$ for a full sinewave cycle of duration t_p (see ST Application Note AN2703).

References

STMicroelectronics Datasheet for BTA06 and BTB06 Series triacs. Available online: **www.st.com/stonline/products/literature/ds/2936/btb06.pdf**

STMicroelectronics Application Note AN2703, *Parameter list for SCRs, triacs, AC switches, and diacs*. Available online: **www.st.com/stonline/products/literature/an/14373.pdf**

This useful document defines all the parameters used on datasheets for these devices.

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

Video from a PIC – Part 3

This month, we will complete the description of the video library introduced last month, and describe a simple demonstration application based loosely on the 1972 video console game 'Pong'.

SCART

Before that, though, let's take a look at an alternative method to output the video and audio signals to a television. We used phono sockets last month, not because they are more popular, but because they are the simplest to connect to. A more common connector for analogue signals is the SCART socket.

Unlike phono sockets, which can often be found on the front of a television, the SCART connector is always tucked away at the back of the set. It's quite a large socket, and on more recent televisions there are often two or more for connecting the wide range of recorders, DVD players and satellite receivers that adorn the modern living room. In Fig.1 is shown the connections on the SCART socket as viewed on the television set itself.

There is a large number of confusing signals, born out of the desire to provide a 'Swiss army knife' solution to all your connectivity needs. Some pins have different features depending on the manufacturer; all very confusing. For us, however, it's quite straight forward – connect the video output of the PIC processor to pin 20 (for video) and pin 17 (for ground), and the audio output from the PIC to pin 6 (audio) and pin 4 (ground). (See Fig.1 and last month's Fig.2.)

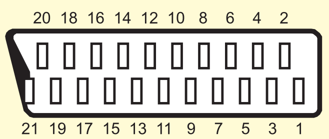
Using two screened cables may be a little overkill if your wires are relatively short, but it may help in reducing noise from the video signal entering the audio channel. Although a SCART is a bulky connector, it is nice to be able to package up the video and audio signals into one tidy cable, and plug it in around the back of the television, out of sight. If you use phono sockets on your own PCB you can purchase an off-the-shelf phono-to-SCART lead available from most technical retail stores.

SCART connectors are readily available from the usual electronics suppliers. Cheap SCART-to-SCART cables can also be purchased from supermarket outlets for as little as £2. The TVs75-208 21-pin SCART lead from Tesco is great value – the two connectors can be easily disassembled, the thick 21-wire cable removed and replaced by a thin dual screened one.

RF

A final suggestion for interfacing to a television for those of you who wish to use an old set without phono or SCART sockets, would be to try salvaging an RF modulator from an old VCR machine, readily available at your local dump (sorry, recycling centre!). RF modulators are typically a small cigarette-packet-sized metal can fitted to the RF output inside VCRs, and are simple to hook up – if you can work out which pins are which.

They normally take a ground, +5V, composite video and audio input only, and give an RF output compatible with a television's antenna input. As to how to work out the pinout of these things, you are on your own – although there are plenty of suggestions on the Internet!



Pin	Function
1	Audio output (right)
2	Audio input (right)
3	Audio output (left or mono)
4	Ground for Audio
5	Ground for RGB Blue
6	Audio input (left or mono)
7	RGB Blue 'up'
8	Status & Aspect Ratio up
9	Ground for RGB Green
10	Clock / Data
11	RGB Green up
12	Reserved
13	Ground for RGB Red
14	Ground for pins 12 & 16
15	RGB Red up
16	Blanking signal up
17	Ground for Composite video output
18	Ground for Composite video input
19	Composite video output
20	Composite video input
21	Ground for pins 8 & 10

Fig.1. Television SCART input socket

Let's get back to the subject of software, and take a look at the details of the video library.

Library functions

To use the library you need to include the files **pic24video.c** and **pic24video.h** in your MPLAB C project. You can copy these files into your project directory if you wish, but normally you would keep these files in a separate directory so they can be shared by any other application you write. The choice is yours, but consider this – if you decide to add a new function to the library, then if you have multiple copies of it, which one do you change? Much better to work with a single copy.

To discover the features available within a library (if you didn't have this article to help!) your first port of call would be the header file (that you include in any source file that needs to manipulate the video features). It's a short file, so we will discuss the parts of interest line by line.

The first lines of interest are the two **#defines** that define the following constants:

VID_WIDTH_PIXELS
VID_DEPTH_PIXELS

These lines tell you the number of pixels available in the x (width) and y (depth) directions.

The following two lines are the most important:

PIC24VIDEO_SETPIX(x,y)
PIC24VIDEO_CLRPIX(x,y)

These are macros that allow you to set individual pixels on (SET) or off (CLR). They are implemented this way because macros are faster than normal function calls. Setting pixels on or off are the most primitive of video operations and must therefore be as quick as possible (although there is plenty of room to improve the speed of these routines – but this is left as an exercise to the reader).

A macro is called in the same way as a function – so to turn on the pixel at the top left corner just add:

PIC24VIDEO_SETPIX(0,0);

to your program.

You should limit the range of values you put into calls to these macros (and indeed all other functions that take pixel coordinates) to valid pixel positions. To help performance, these routines do no checking of the values sent to them. Trying to display a pixel at an invalid position will probably crash your application.

The next line in the header file is the main function you call to initialise the video hardware. You should call it once your application is ready to start displaying 'stuff' on the screen. The simple line

PIC24VideoInit();

is all that is required.

The following function in the header file requires a little more explanation. **PIC24VideoWaitFrame()** is a function that will wait until the main interrupt-based video software has completed the display of a screen full of data. When this happens the function will return, allowing your software to continue.

For about the next 10ms to 15ms your application will be able to run at full speed, as nothing is being written to the screen. This can be useful if you want to do some intensive software processing or write to the display without the possibility of having the video library write your data to the screen while you are still generating it – which can cause some slight jitter in the display. Feel free to ignore this function, but consider adding it if you are updating the display rapidly and notice unpleasant display glitches.

PIC24VideoCls() is a function that will clear the display to black, and is commonly called immediately after or just prior to the **PIC24VideoInit()** call. It can be quite interesting to leave it out, and see what the contents of memory look like. It's an unusual way to visualise the contents of RAM.

PIC24VideoDrawRect() will draw a filled rectangle. The four parameters define the top left and bottom right corners of the rectangle.

PIC24VideoClearRect() will have the opposite effect, turning off the defined rectangular area.

PIC24VideoDelayms() and **PIC24VideoDelays()** are routines that will halt for the defined number of milliseconds or seconds specified. Although not related to video generation, they are implemented here because they are useful functions.

PIC24VideoPlayNote() is the function that generates sound output. It's a simple implementation that can generate a continuous tone for a given duration or until the **PIC24VideoStopNote()** function is called.

The duration parameter is in multiples of 20ms (tied to the frame rate time). The **freq** parameter is really a timer reload value, and so is not actually the frequency of the sound – 60000 gives a tone of approximately 1kHz.

PIC24VideoPutChar() and **PIC24VideoPutStr()** provide text output to the display, in a similar way to the standard **putc()** and **puts()** functions in the standard C libraries. The x and y parameters allow you to specify exactly where on the display the text is displayed.

These routines work by having a lookup table for bitmaps for each character, which can be found in the file **font5x7.h**. This font is based loosely on the standard 2 x 16 character LCD that is a favourite of *EPE* constructional articles. Feel free to modify it if you wish.

There are several other routines that could be added to the basic library; line, circle and arc drawing routines are quite common. We will add these to the library over the coming months, but they are easy enough to implement within your own application using the **PIC24VIDEO_SETPIX** routine.

You may be wondering why all the routines have the text 'PIC24Video' at the beginning. This is to make sure that when you include the video library code in your own projects, you will not risk getting a 'clash' between the names of routines in our code and yours.

Had we called **PIC24VideoInit()** simply **init()**, there would be a good chance your own code would have a function with a similar name. This is a useful trick to remember when writing your own library code.

Frame buffer

The frame buffer is an area of RAM in your processor (that we choose) that stores the state of every pixel that will be displayed on the screen. As we are using black and white pixels, that means one 'bit' per pixel, or eight pixels in every byte. Our screen resolution is 208 by 240 pixels, so our frame buffer is 6240 bytes, which leaves 1952 bytes for your own application. We define the frame buffer as a simple unsigned integer array in the main video library C source file.

It's quite acceptable for your application to write data to the frame buffer at the same time as the video library's interrupt routine is reading it; at worst, you may notice a slight 'glitch' in the image on the screen, but it will only last for 20ms or so.

If you are continuously writing to the display then the glitches may become noticeable. If this is the case, calling the function **PIC24VideoWaitFrame()** before writing to the frame buffer will ensure that your writes will not occur at the same time as the display is being updated.

```
loop:

    wait for display update to complete

    erase the current bat and ball images

    calculate the new ball position

    test for the ball hitting a wall
      change direction if so

    test for the ball going into a goal
      update score if so

    test for the ball hitting a bat
      change direction if so

    test for bat movement
      change position if so

      re-draw new ball position

    test for game finished

While game not finished
```

Fig.2. Main game loop description

Switches

You may have noticed that there are no software routines in our video library to handle the switches shown on last month's circuit diagram. That's because the switches have nothing to do with the video library, and are only present in this design to support our example application.

Pong

The example application that shows off the video library can be found in the file **videotest.c**. This is a simple rendition of the classic 1970s game Pong, which involved two players each controlling a 'bat' that can move up and down at each end of the screen. A small square, representing a ball, moves from one side of the screen to the other. if you position your bat in the path of the ball it bounces off and moves back in the opposite direction. If you miss, and the ball is in line with your 'goal', your opponent gains a point. A simple game, but in the early 1970s it was a smash hit with kids (like the author!).

Our application was 'knocked up' very quickly in a few evenings, and the quality of the code found in **videotest.c** will attest to this. That was deliberate; we wanted to show how simple the library is to use, without requiring complex timing or carefully arranged instruction sequences.

The application starts off by defining a standard set of config register values, including the video library header file. We also '#include' the file **logo.h,** which contains a series of bytes that define the logo first shown on power up.

The two variables 'bat' and 'ball' are used to hold the current location of the objects that can move on screen. Everything else is static and is drawn once at startup, so we don't need variables to hold information about those. Only three other global variables are defined; two to hold the scores, and another to indicate when the game has finished.

The single **main()** function follows. First we switch the processor oscillator to full speed (80MHz) as required by the video library. Then the important call to **PIC24VideoInit()** starts up the video system. We then do a simple **memcpy()** call to transfer the bitmap defined in **logo.h** to the frame buffer.

After a short delay we enter the first of two loops. This first loop is responsible for starting each new game; it displays a prompt to press the middle button on the controller, and then waits for one of the two middle buttons to be pressed.

Once pressed, the software clears the display to black and then uses the **PIC24VideoDrawRect()** function to draw a single pixel wide border around the screen. We then initialise the 'bat' and 'ball' variables to indicate the starting positions, and enter the main game loop.

The game loop is quite simple, and repeats the steps shown in Fig.2. All of the display updates caused by calls to **PIC24VideoDrawRect** and others result in the instant update to the frame buffer; the display will only change when the next video interrupt goes off. As this happens every 20ms or so, the eye just sees a smooth continuous update.

It's a very simple game, but fun to play with. Each player has three buttons for up down and boost – the latter causing the ball to speed up, if you press it when the ball hits your bat.

There are many games which could easily be put together in this way; *Breakout* and *Tetris* spring to mind, as well as the old *Adventure* game which first appeared on the Atari games console. The source code for *Maze Wars*, one of the earliest 3D computer games, is available on the Internet and porting it to the PIC processor would make a fantastic challenge for some intrepid programmer. If your are interested, contact the author, and he will point you in the right direction.

Next month

Next month we take a look at turning your old television into an RS232 display terminal, and then move onto driving LCD monitors using RGB VGA video signals.

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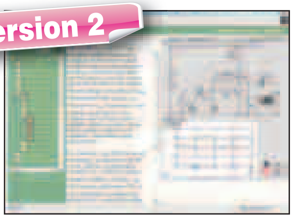

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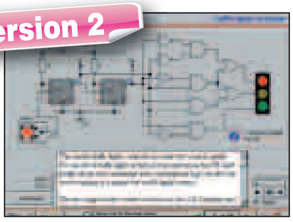
Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: ***Fundamentals*** – Analogue Signals (5 sections), Transistors (4 sections), Waveshaping Circuits (6 sections). ***Op Amps*** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. ***Amplifiers*** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). ***Filters*** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). ***Oscillators*** – 6 sections from Positive Feedback to Crystal Oscillators. ***Systems*** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

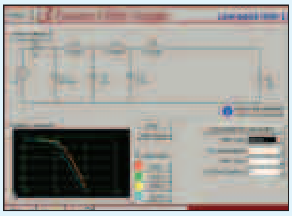
Version 2



Virtual laboratory - Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (above), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

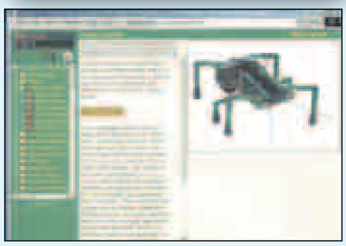
ANALOGUE FILTERS



Filter synthesis

Analogue Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student	£44	inc VAT
Institutional (Schools/HE/FE/Industry)	£99	plus VAT
Institutional 10 user (Network Licence)	£249	plus VAT
Site licence	£499	plus VAT

(UK and EU customers add VAT at 15% to 'plus VAT' prices)

PICmicro TUTORIALS AND PROGRAMMING

HARDWARE

VERSION 3 PICmicro MCU development board

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
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- Fully protected expansion bus for project work
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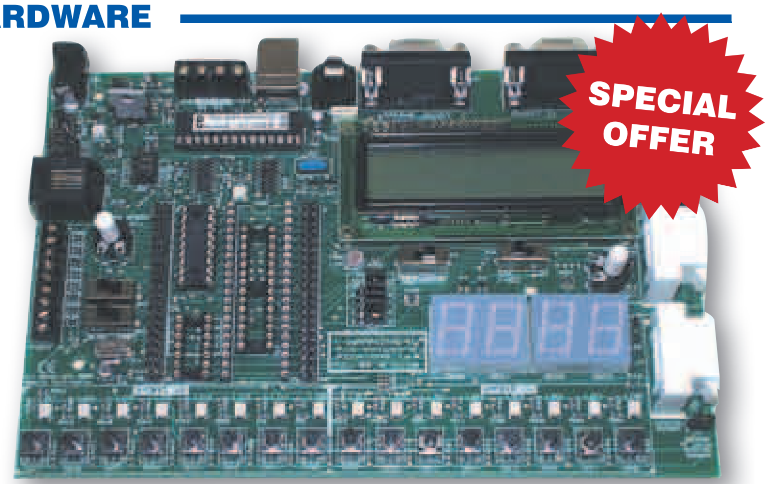


£155 including VAT and postage, supplied with USB cable and programming software

£40 OFF Buy the Development Board together with any Hobbyist/Student or Institutional versions of the software CD-ROMs listed below and take £40 off the total (including VAT) price.

SOFTWARE

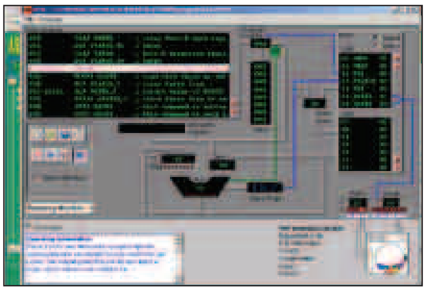
ASSEMBLY FOR PICmicro V3

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

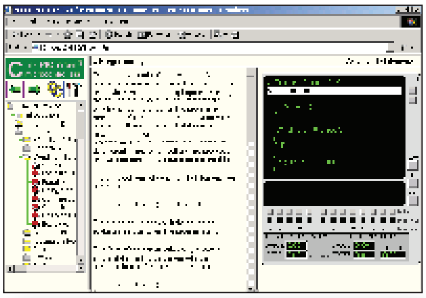


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

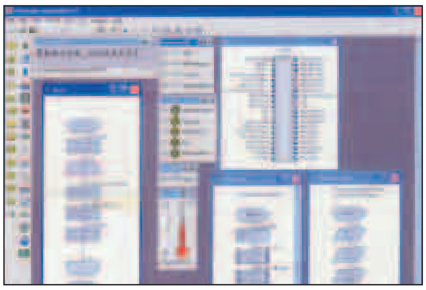
FLOWCODE FOR PICmicro V3

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A Powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and l.c.d.'s. The use of macros allows you to control these devices without getting bogged down in understanding the programming.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols ● Full on-screen simulation allows debugging and speeds up the development process.

● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 18, 28 and 40-pin devices ● New features in Version 3 include 16-bit arithmetic, strings and string manipulation, improved graphical user interface and printing, support for 18 series devices, pulse width modulation, I2C, new ADC component etc. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

Hobbyist/Student	£44	inc VAT
Institutional (Schools/HE/FE/Industry)	£99	plus VAT
Institutional/Professional 10 user (Network Licence)	£300	plus VAT
Site licence	£599	plus VAT
Flowcode 10 user (Network Licence)	£350	plus VAT
Flowcode 50 user (Network Licence)	£699	plus VAT

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SPECIAL PACKAGE OFFER

TINA Pro V7 (Basic) + Flowcode V3 (Hobbyist/Student)

TINA Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode Circuit Simulation, Testing and PCB Design

£50.00 inc. VAT and p&p

TINA Design Suite is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

Enter any circuit (up to 100 nodes) within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments. Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create, and print documents directly inside TINA or cut and paste your results into your favourite word- procesing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.

***Flowcode V3** (Hobbyist/Student) – For details on Flowcode, see the previous page.*

This offer gives you two seperate CD-ROMs in DVD style cases – the software will need registering (FREE) with Designsoft (TINA) and Matrix Multimedia (Flowcode), details are given within the packages.

Get TINA + Flowcode for a total of just £50, including VAT and postage.

PROJECT DESIGN WITH CROCODILE TECHNOLOGY

An Interactive Guide to Circuit Design

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An interactive CD-ROM to guide you through the process of circuit design. Choose from an extensive range of input, process and output modules, including CMOS Logic, Op-Amps, PIC/PICAXE, Remote Control Modules (IR and Radio), Transistors, Thyristors, Relays and much more.
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Nearly all the circuits can be instantly simulated in Crocodile Technology (not included on the CD-ROM) and you can customise the designs as required.*

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All circuits can be viewed, but can only be simulated if your computer has Crocodile Technoloy version 410 or later. A free trial version of Crocodile Technology can be downloaded from: **www.crocodile-clips.com. Animated diagrams run without Crocodile Technology.*

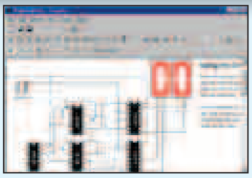
Single User £39.00 inc. VAT.

Multiple Educational Users (under 500 students) £59.00 plus VAT. Over 500 students £79.00 plus VAT.

(UK and EU customers add VAT at 15% to "plus VAT" prices)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME/XP, mouse, sound card, web browser.

DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.

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ELECTRONIC COMPONENTS PHOTOS

A high quality selection of over 200 jpg images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Now contains Irfan View image software for Windows, with quick-start notes included.

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READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly

★ LETTER OF THE MONTH ★

Nixie tube drivers

Dear EPE

Further to your *Editorial* comments in the April issue, here are a few notes on Nixie tube drivers.

Looking back, it is surprising to realise that the integrated circuit (IC) predates LED and LCD displays by several years. Early digital counting circuits had to rely on a variety of display devices, of which gas-filled discharge tubes with electrodes in the shape of decimal digits were, perhaps, the most popular. These were generally known as 'Nixie' tubes, although I believe this was a trade name.

Unfortunately, gas discharge tubes have a striking voltage of around 170V, which implies a power supply of at least 200V. Nevertheless, IC technology rose to the challenge and devices capable of driving these displays directly were available. These were the 7441 and 74141 (the absence of interposed letters means that they were members of the original 74 series devices).

These ICs were 4-line binary coded decimal (BCD) to 10-line decimal decoders with output stages rated to withstand at least 60V. Their outputs could be connected directly to the cathodes of the display tube. The only other connections required were a common-anode supply fed via a current-limiting resistor (typically 33kΩ for a 200V supply). The sole difference between the two devices is that the later 74141 featured blanking for invalid input combinations (greater than decimal 9) whereas the 7441 did not.

Sadly, for the present day user, these devices have long been obsolete. They may be available, at a price, from specialist suppliers (for example, Cricklewood list them at £4 and £5). This may seem expensive for a single chip, but the only practical alternative would seem to be a currently available BCD to decimal decoder (eg, the 4028) followed by ten suitably rated transistors (eg, BC546 or ZTX651). This would cost slightly less, but would be rather tedious to assemble on stripboard or a printed circuit board.

Dr John Nelson, Leeds

Thank you for this historical overview and practical advice on driving Nixies. A quick scan of eBay shows that these devices are very much alive and being used, so I'm sure readers will appreciate your notes.

More Nixies

Dear EPE

I'm not a Nixie tube expert, but I hope the accompanying photograph will be of interest. It shows three numeric indicator tubes that are in my possession, probably not officially 'Nixie' tubes as I think that this is a trade name.

Looking at the photograph (left to right) there is a Mullard ZM1175, which is like a Nixie. This cold-cathode display is in a glass envelope about three-quarters of an inch diameter. Applying a couple of hundred volts, via a 100k resistor in series with the common anode produces a good glow. More than one cathode may be illuminated simultaneously, hence both the figure '9' and the decimal point are showing.

Interestingly, the shaped cathodes are not mounted in numerical order, figure '6' is nearest to the viewing point. I don't know if this is to minimise the obstruction that un-illuminated nearer characters cause to the deeper-set figures, or if it's to simplify construction. The base pinout is shown in the separate diagram.

An interesting development, which was almost 'digital electronics in thermionic form' was the self-counting tube. The displays on these step over one place each time a 'clock' pulse is received.

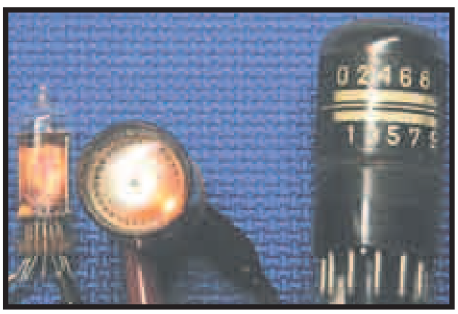
In the middle of the photo is a GC10B 'Dekatron', with one position illuminated. Again, it's a cold-discharge device. A marking engraved on the adjacent panel indicates the numeric value of each individual point of illumination; the tube itself simply shows points of light.

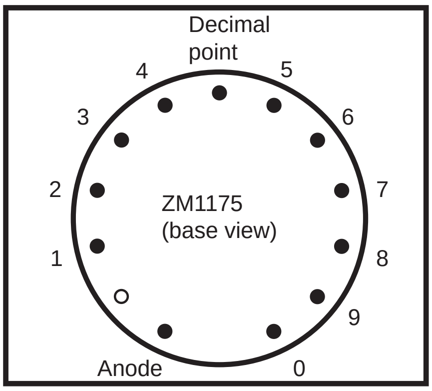
Another type, on the right in the photo, is the Philips E1T, which sadly is not working – although you can just see its heater glowing orange. The internal beam is deflected according to received pulses and illuminates spots on the white screen behind the numeric annotations, not unlike the way in which 'magic eye' indicators have a phosphor screen.

Both self-counting tubes have a carry-over function so as to cascade on to the next tube, thus providing a multi-digit display.

Godfrey Manning G4GLM, Edgware

Fine examples, thank you Godfrey





Dear EPE

I read the *Editorial* of the April 09 issue of *EPE* where you mentioned Nixie tubes. Here is a link to a site / person who may be able to help with an article – the link is **http://www.dos4ever.com/index.html**.

Thanks for a great magazine.

Richard Sullivan, by email

…and thank you Richard – Nixie fans will find a wealth of material here.

WARNING

Please remember that Nixie tubes and similar devices require dangerously high voltages. You must not tackle these devices unless you know what you are doing or are suitably supervised. Safety first – always!

Net Work

Alan Winstanley

This month's *Net Work* column starts off by highlighting the newest 'elephant' coming down our collective pipelines, in the shape of Microsoft Internet Explorer 8. The latest update to Microsoft's browser will arrive as part of Windows automatic updates, but you can opt out of installing it. You can read more or fetch it now from **www.microsoft.com/ie8**.

For more advanced Windows users, network or system administrators who need to prevent this monolithic download landing on desktops, Microsoft has released an IE8 Download Blocker Toolkit available from **http://tinyurl.com/9yjpqw**.

This upgrade, however, is not as trivial as it seems. A major aspect that affects both website users and web designers is IE8's 'Compatibility Mode'. This allows IE8 to render websites as though you were viewing in the old current IE7. Why would you need to do this?

A decade or more ago, web surfers had a limited range of browsers to choose from. Netscape Navigator 1.0 (which has morphed into the Mozilla Firefox of today) was the mainstream web browser used by 75% of the end-user market, and people would actually buy Navigator with real money because it was licensed shareware. Netscape held an 'amnesty' to encourage illegal downloaders to cough up £15.00 ($22). Gradually, Internet Explorer worked its way into the PC desktop of today; Wikipedia has a useful summary at **http://en.wikipedia.org/wiki/History_of_Internet_Explorer**

Web designers had to cater for users of IE4 or Netscape because there were some serious differences with how the two browsers handled source code. Designers would often 'optimise' a site for one browser or the other, or some bigger-budget sites would send visitors to a version of the website optimised just for their browser: duplicating the design effort and costs. Things settled down once IE7 arrived and designers could breathe a sign of relief.

In an ideal world wide web

Technically, it wasn't the 'compliant' web page source code that was faulty, but the web browser's non-compliant interpretation of it. In practice, web source code was engineered to compensate for the shortcomings of web browsers, as a way of forcing web browsers to do what designers wanted them to do.

Which brings us to the impending arrival of Internet Explorer 8. Websites are still generally 'optimised' for today's browsers and the source code is often written with the quirks and foibles of IE7 in mind. Hence Microsoft declares that "some web sites may not yet be ready for Internet Explorer 8." Many present generation web sites, which were designed with IE7 in mind, could now break in one way or another, because they inherently contain 'non compliant' code to compensate for a 'non-compliant' web browser to begin with!

IE8 lays bare these compatibility problems and designers now face a rethink to make their sites run in IE8. Some major global websites have a major design headache on their hands. Problems include page layout errors, totally scrambled text and operability problems. Some issues may be trivial and can be ignored, but tests showed that some sites may not work at all if viewed in IE8.

To counter this, IE8 has a Compatibility View feature that renders websites as they would appear in IE7. Designers can also add code to force IE8 to treat it like an IE7 compatible page. It is believed that Compatibility View is not a blanket setting and must be enabled on each website visited. The Compatibility View button promises to be the most overworked icon in the new browser.

Other new features in IE8 include Grouped tabs, enabling associated website tabs to be bunched together, and you can at last reopen your carefully-arranged tabs and websites and carry on where you left off, in case you have accidentally shut the browser. A new InPrivate mode does not cache web files (similar to Google Chrome's Incognito mode), so you can cover your footsteps. New 'Web Slices' allow users to track any changes in a slice or segment of a website (eg, an item for sale on eBay). Improvements to Favorites and Histories are also promised. Internet Explorer 8 is on the way – so be sure to locate that Compatibility Mode button as a first step!

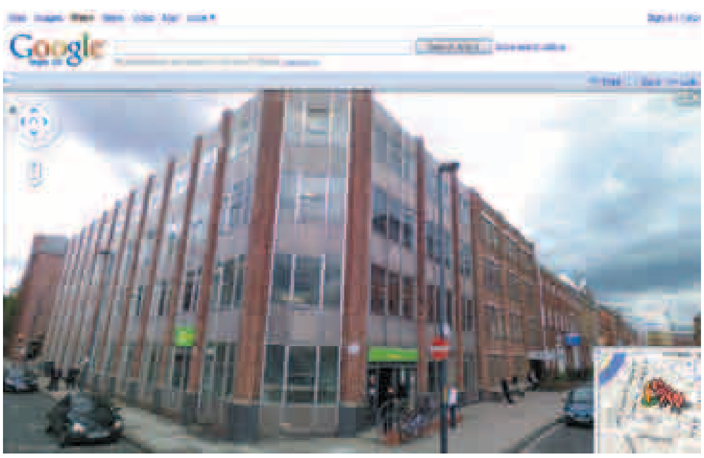
Google Street View – yoo hoo!

I mentioned Google Street View in the past when it started a rollout in the USA. The British media has been full of Google's Street View project, which involves fleets of sinister-looking black Opel camera cars taking panoramic photos of British town and cities, and stitching them together to make a photo-montage snapshot of our streets.

One group of English villagers linked arms to prevent Google's car from exposing their rural idyll. A chorus of protests from citizens about invasion of privacy brought the stock response from Google that it's all entirely legal, and if you don't like what you see, you can 'report a problem' and Google will delete the image. The flip-side of the coin, I guess, is that if an entire street has been deleted, there must be something there worth looking into. The house of a good friend in Leeds is photographed perfectly, and his neighbour will not appreciate the fact that his Rolls Royce appears larger than life in the driveway, complete with personal number plate (which Google's automatic software has failed to obscure). A burglar's charter indeed!

I admit that I would not like a telescopic camera peering through my front window, nor would Mrs W like the contents of the washing line to be preserved for posterity on Google. I do wonder whether Street View is one clever step too far, or whether people are over-reacting to the shock of seeing a snapshot of their personal world plastered all over the web; it isn't as though the whole world is suddenly tuning in to see the decorations of your front room in 3D colour, though it probably feels like that if you're not used to Google's omnipresence.

There are undoubtedly some privacy and security issues arising, and I believe Google is being naïve and disingenuous in its quest to publish a 3D and satellite snapshot of our entire world. Some things in life are best left undisturbed. Google does this sort of thing because it can, so all you can do for now is hit that Report A Problem link – because you can, too! Be sure to check my monthly *Net Work* blog at **www.epemag.com.** You can email me at **alan@epemag.demon.co.uk.**



On your bike: Google Street View photographs a Job Centre employment exchange in Leeds

Electronics Teach-In + FREE CD-ROM

Mike Tooley

A broad-based introduction to electronics – find out how circuits work and what goes on inside them. Plus 15 easy-to-build projects. The 152 page A4 book comes with a free CD-ROM containing the whole Teach-In 2006 series (originally published in *EPE*) in PDF form, interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

In addition to the Teach-In series, the book includes 15 CMOS-based simple projects from the Back-To-Basics series by Bart Trepak, these are: Fridge/Freezer Alarm, Water Level Detector, Burglar Alarm, Scarecrow, Digital Lock, Doorchime, Electronic Dice, Kitchen Timer, Room Thermometer, Daily Reminder, Whistle Switch, Parking Radar, Telephone Switch, Noughts and Crosses Enigma and a Weather Vane. There is also a MW/LW Radio project in the Teach-In series.

152 pages + CD-ROM | **Order code ETI** | **£8.50**

ROBOTICS

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Then explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages - large format | **Order code BP901** | **£14.99**

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

198 pages | **Order code BP902** | **£14.99**

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots; Robotic Locomotion; Motors and Power Controllers; All Types of Sensors; Tilt; Bump; Road and Wall Detection; Light; Speech and Sound Recognition; Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC; Robotic Intelligence (Neutral Type) Using Simple Neural Networks (Insect Intelligence); Making a Lifelike Android Hand; A Computer-Controlled Robotic Insect Programmed in BASIC; Telepresence Robots With Actual Arcade and Virtual Reality Applications; A Computer-Controlled Robotic Arm; Animated Robots and Androids; Real-World Robotic Applications.

224 pages | **Order code MGH1** | **£16.99**

DIRECT BOOK SERVICE

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS SEE THE NEXT TWO ISSUES OF *EPE*

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All prices include UK postage

RADIO

BASIC RADIO PRINCIPLES AND TECHNOLOGY
Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation; Receivers; Transmitters; Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages | **Order code NE30** | **£20.00**

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages | **Order code BP304** | **£4.45**

AN INTRODUCTION TO AMATEUR RADIO
I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the last century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages | **Order code BP257** | **£5.49**

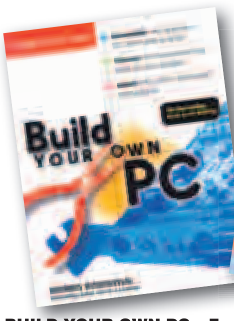
COMPUTERS AND COMPUTING

THE INTERNET FOR THE OLDER GENERATION
Jim Gatenby

Especially written for the over 50s. Uses only clear and easy-to-understand language. Larger type size for easy reading. Provides basic knowledge to give you confidence to join the local computer class.

This book explains how to use your PC on the Internet and covers amongst other things: Choosing and setting up your computer for the Internet. Getting connected to the Internet. Sending and receiving emails, photographs, etc., so that you can keep in touch with family and friends all over the world. Searching for and saving information on any subject. On-line shopping and home banking. Setting up your own simple web site.

228 pages | **Order code BP600** | **£8.99**



BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format | **Order code MGH2** | **£16.99**

THE PIC MICROCONTROLLER YOUR PERSONAL INTRODUCTORY COURSE – THIRD EDITION
John Morton

Discover the potential of the PIC microcontroller through graded projects – this book could revolutionise your electronics construction work!

A uniquely concise and practical guide to getting up and running with the PIC Microcontroller. The PIC is one of the most popular of the microcontrollers that are transforming electronic project work and product design.

Assuming no prior knowledge of microcontrollers and introducing the PICs capabilities through simple projects, this book is ideal for use in schools and colleges. It is the ideal introduction for students, teachers, technicians and electronics enthusiasts. The step-by-step explanations make it ideal for self-study too: this is not a reference book – you start work with the PIC straight away.

The revised third edition covers the popular reprogrammable Flash PICs: 16F54/16F84 as well as the 12F508 and 12F675.

270 pages | **Order code NE36** | **£20.99**

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24
Lucio Di Jasio (Application Segments Manager, Microchip, USA)

FREE CD-ROM

A Microchip insider tells all. Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compiler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

Until recently, PICs didn't have the speed and memory necessary for use in designs such as video- and audio-enabled devices. All that changed with the introduction of the 16-bit PIC family, the PIC24. This new guide teaches readers everything they need to know about the architecture of these chips, how to program them, how to test them and how to debug them. Lucio's common-sense, practical, hands-on approach starts out with basic functions and guides the reader step-by-step through even the most sophisticated programming scenarios.

Experienced PIC users and newcomers alike will benefit from the text's many thorough examples, which demonstrate how to nimbly side-step common obstacles and take full advantage of all the 16-bit features.

496 pages +CD-ROM | **Order code NE45** | **£32.99**

THEORY AND REFERENCE

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS
Third Edition
Mike Tooley

A comprehensive reference text and practical electronics handbook in one volume – at an affordable price!

New chapter on PIC microcontrollers – the most popular chip family for use in project work by hobbyists and in colleges and universities.

New companion website: spreadsheet design tools to simplify circuit calculations; circuit models and templates to enable virtual simulation; a bank of on-line questions for lecturers to set as assignments, and on-line self-test multiple choice questions for each chapter with automatic marking, to enable students to continually monitor their progress and understanding.

The book's content is matched to the latest pre-degree level courses, making this an invaluable reference for all study levels, and its broad coverage is combined with practical case studies, based in real-world engineering contexts throughout the text.

The unique combination of a comprehensive reference text, incorporating a primary focus on practical applications, ensures this text will prove a vital guide for students and also for industry-based engineers, who are either new to the field of electronics, or who wish to refresh their knowledge.

400 pages **Order code NE43** **£23.99**

BEBOP TO THE BOOLEAN BOOGIE
Third Edition
Clive (Max) Maxfield

BOOK + CD-ROM

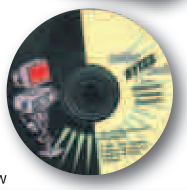
This book gives the "big picture" of digital electronics. This indepth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate. Comes with a free CD-ROM which contains an eBook version with full text search plus bonus chapter – An Illustrated History of Electronics and Computing.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

500 pages **Order code BEB1** **£32.95**

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

CD-ROM



This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. If you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM **Order code BEB2 CD-ROM** **£21.95**

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES
Third Edition
C. R. Robertson

Covers the essential principles that form the foundations for electrical and electronic engineering courses. The coverage of this new edition has been carefully brought in line with the core unit 'Electrical and Electronic Principles' of the 2007 BTEC National Engineering specification. This qualification from Edexcel attracts more than 10,000 students per year.

The book explains all theory in detail and backs it up with numerous worked examples. Students can test their understanding with end of chapter assignment questions for which answers are provided. In this new edition, the layout has been improved and colour has been added. A free companion website with additional worked examples and chapters is also available.

368 pages **Order code NE47** **£21.95**

STARTING ELECTRONICS
Third Edition
Keith brindley

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

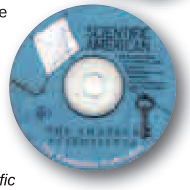
A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

288 pages **Order code NE4** **£12.99**

THE AMATEUR SCIENTIST CD-ROM – VERSION 2

CD-ROM



The complete collection of The Amateur Scientist articles from *Scientific American* magazine. Over 1,000 classic science projects from a renowned source of winning projects. All projects are rated for cost, difficulty and possible hazards. Plus over 1,000 pages of helpful science techniques that never appeared in *Scientific American*.

Exciting science projects in: Astronomy; Earth Science; Biology; Physics; Chemistry; Weather . . . and much more! The most complete resource ever assembled for hobbyists, and professionals looking for novel solutions to research problems. Includes extensive Science Software Library with even more science tools. Suitable for Mac, Windows, Linux or UNIX. 32MB RAM minimum, Netscape 4.0 or higher or Internet Explorer 4.0 or higher. Over 1,000 projects.

CD-ROM **Order code ASI CD-ROM** **£19.95**

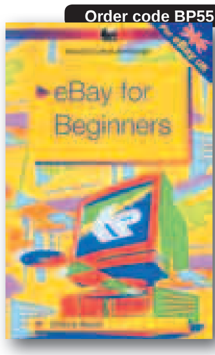
eBAY FOR BEGINNERS
Cherry Nixon

There are two kinds of people, those who are trading on eBay and the rest who are missing out. Though eBay has been embraced by entrepreneurs all over the world, it remains the peoples' site and offers the largest market for the smallest fee.

eBay presents an opportunity for everyone, the trick is to master it. This book shows you how to start trading on eBay UK. It also offers advice on getting organised and tips to put you ahead.

The book has been developed from Cherry's popular hands-on course "Buying and Selling on eBay for Technological Simpletons". In addition to fully explaining eBay and how to trade on it there are sections on Paypal, producing pictures of your sale items, fees and accounts, safety and security, including what to do when things go wrong and what protection is provided.

178 pages **Order code BP551** **£8.99**



MUSIC, AUDIO AND VIDEO

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett

Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.

You'll learn about recording techniques, software and effects, mixing, mastering and CD production.

Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages **Order code PC120** **£10.95**

QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh

MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?

All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:

How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.

Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

60 pages **Order code PC119** **£7.45**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages **Order code PC115** ~~£10.95~~ **£5.45**

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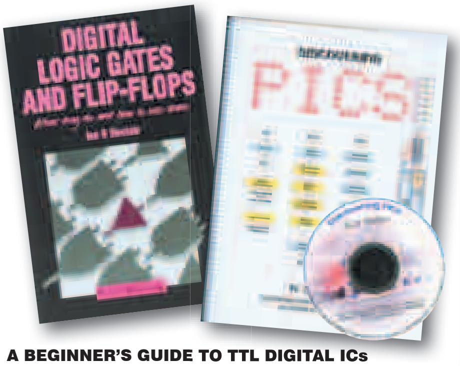
DATA AND DESIGN

PRACTICAL ELECTRONIC FILTERS
Owen Bishop
This book deals with the subject in a non-mathematical way. It reviews the main types of filter, explaining in simple terms how each type works and how it is used.
The book also presents a dozen filter-based projects with applications in and around the home or in the constructor's workshop. These include a number of audio projects such as a rythm sequencer and a multi-voiced electronic organ.
Concluding the book is a practical step-by-step guide to designing simple filters for a wide range of purposes, with circuit diagrams and worked examples.

88 pages Order code BP299 £5.49

DIGITAL LOGIC GATES AND FLIP-FLOPS
Ian R. Sinclair
This book, intended for enthusiasts, students and technicians, seeks to establish a firm foundation in digital electronics by treating the topics of gates and flip-flops thoroughly and from the beginning.
Topics such as Boolean algebra and Karnaugh mapping are explained, demonstrated and used extensively, and more attention is paid to the subject of synchronous counters than to the simple but less important ripple counters.
No background other than a basic knowledge of electronics is assumed, and the more theoretical topics are explained from the beginning, as also are many working practices. The book concludes with an explanation of microprocessor techniques as applied to digital logic.

200 pages Order code PC106 £9.95



A BEGINNER'S GUIDE TO TTL DIGITAL ICs
R. A. Penfold
This book first covers the basics of simple logic circuits in general, and then progresses to specific TTL logic integrated circuits. The devices covered include gates, oscillators, timers, flip/flops, dividers, and decoder circuits. Some practical circuits are used to illustrate the use of TTL devices in the "real world".

142 pages Order code BP332 £5.45

MICROCONTROLLER COOKBOOK
Mike James
The practical solutions to real problems shown in this cookbook provide the basis to make PIC and 8051 devices really work. Capabilities of the variants are examined, and ways to enhance these are shown. A survey of common interface devices, and a description of programming models, lead on to a section on development techniques. The cookbook offers an introduction that will allow any user, novice or experienced, to make the most of microcontrollers.

240 pages Order code NE26 £25.99

RADIO BYGONES

We also carry a selection of books aimed at readers of *EPE*'s sister magazine on vintage radio *Radio Bygones*. These books include, the four volumes of our own *Wireless For the Warrior* by Louis Meulstee. These are a technical history of radio communication equipment in the British Army and clandestine equipment from pre-war through to the 1960s.
For details see the shop on our UK web site at www.epemag.com or contact us for a list of *Radio Bygones* books.

PROJECT BUILDING AND TESTING

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages Temporarily out of print

ELECTRONIC PROJECTS FOR EXPERIMENTERS
R. A. Penfold
Many electronic hobbyists who have been pursuing their hobby for a number of years seem to suffer from the dreaded "seen it all before" syndrome. This book is fairly and squarely aimed at sufferers of this complaint, plus any other electronics enthusiasts who yearn to try something a bit different. No doubt many of the projects featured here have practical applications, but they are all worth a try for their interest value alone.
The subjects covered include:- Magnetic field detector, Basic Hall effect compass, Hall effect audio isolator, Voice scrambler/descrambler, Bat detector, Bat style echo location, Noise cancelling, LED stroboscope, Infra-red "torch", Electronic breeze detector, Class D power amplifier, Strain gauge amplifier, Super hearing aid.

138 pages Order code BP371 £5.45

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages Order code BP374 £5.45

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

96 pages Order code BP239 £5.49

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PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU. Tel: 01202 873872; Fax 01202 874562; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue. A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE	COST
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– PSU	659 }	
Electrosmog Sniffer	660	£5.71
MARCH '08		
Fluorescent Tube Driver	661	£7.13
Studio Series – Stereo Headphone Amplifier	662	£8.24
APRIL '08		
★ Studio Series – Remote Control Module	663	£7.13
★ MIDI Activity Detector	664	£6.34
PIC In-Circuit Programming Add-On	665	£5.39
★ PC-Controlled Burglar Alarm – Main Board	666 } set	£11.89
– Display Board	667 }	
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★Electric Mobility Buggy Monitor	669	£6.02
Mini Theremin	670	£10.15
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★ Monopoly Money	671	£7.30
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★ PIC MIDI Sound Wave Generator	672	£11.20
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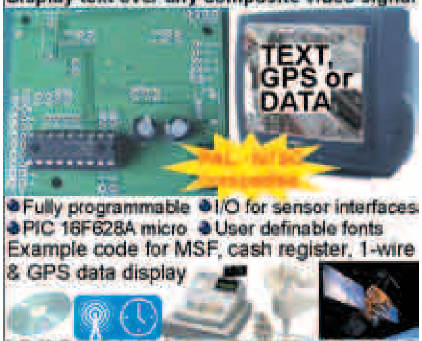

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